LBO-525L

50 MHz delayed time base oscilloscope

$30

instruction manual

For professionals who know the difference.

LEADER Instruments Corporation

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LBO-525L

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1. GENERAL INFORMATION

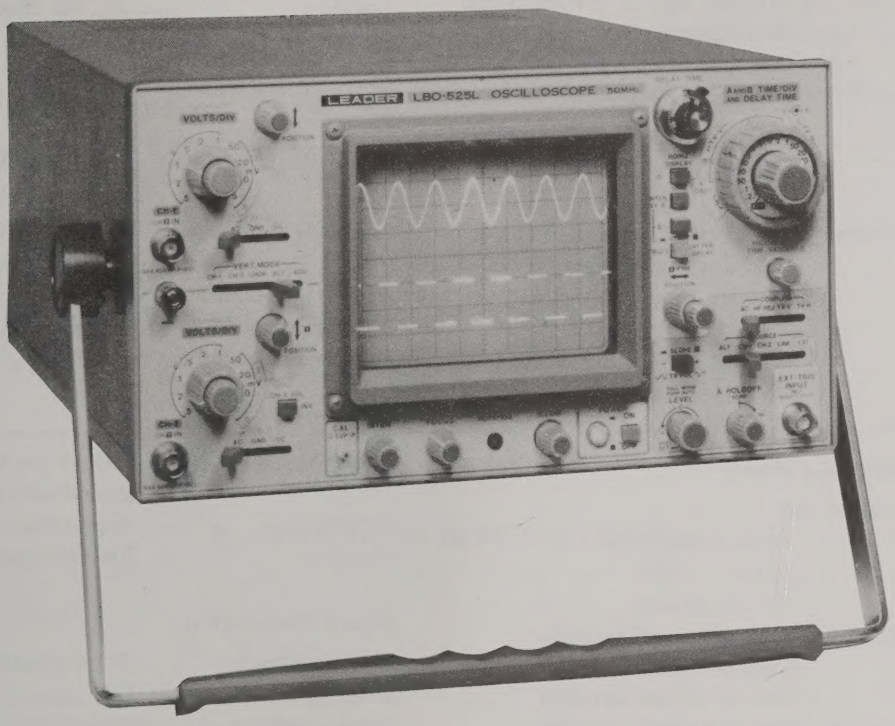


Figure 1-1. Model LBO-525L Dual-Trace Oscilloscope

1-1 INTRODUCTION

The LBO-525L, shown in Figure 1-1, is a 50 MHz oscilloscope with many high performance characteristics: including accurate high speed pulse response, extremely stable waveform display, dual timebases with sweep delay, comprehensive triggering facilities, a bright CRT display, channel 1 amplifier output, extremely-high sensitivity, and a delay line.

Amplitude measurement accuracy is enhanced by precision step attenuators and a CRT with internal graticule for the prevention of parallax error. Similarly, time-interval measurement accuracy is enhanced by a calibrated delay-time multiplier and sweep magnification.

The triggering facilities of the LBO-525L include several features that greatly reduce the problem of triggering on complex or noisy signals: a variety of frequency-selective coupling filters, a sweep holdoff control, and a trigger pick-off mode that alternates the trigger source between the two vertical channels.

1-2 SPECIFICATIONS

Specifications for the model LBO-525L oscilloscope is given in Table 1-1. Specifications for the model LP-050X scope probes are given in Table 1-2.

Table 1-1
LBO-524 SPECIFICATIONS

Vertical Amplifiers (Ch. 1 & 2)	
Bandwidth (-3 dB, 8 div.)	
DC coupled	DC to 50 MHz normal
	DC to 5 MHz magnified
AC coupled	10 Hz to 50 MHz normal
	10 Hz to 5 MHz magnified
Risetime	7 nS normal
	70 nS magnified

Deflection Coefficients	5 mV/div to 5 V/div in 10 calibriated, steps, 1-2-5 sequence. Continuously variable between steps. 10X magnifier adds .5 mV/div; and 2 mV/div steps for frequencies below 5 MHz.
Accuracy	±3% normal ±5% magnified
Input Impedance	1 megohm ±1.5%, 30 pF ±5 pF
Maximum Input Voltage	600 V (DC plus AC peak)
Vertical Display Modes	CH-1 only, CH-2 only, CH-1 & CH-2 displayed alternately, CH-1 & CH-2 chopped (switched at 250 kHz rate), CH-1 & CH-2 added, CH-1 & CH-2 subtracted (by inverting CH-2)
Channel 1 Output	50 mV/div into 50 ohms

Horizontal Amplifier (X-Y Mode)

Bandwidth (-3 dB, 8 div)	
DC coupled	DC to 1 MHz
AC coupled	10 Hz to 1 MHz
Phase Shift	<3° at 100 kHz
Deflection Coefficients	Same as Vertical Amplifier
Accuracy	Same as Vertical Amplifier
Input Impedance	Same as Vertical Amplifier
Maximum Input Voltage	Same as Vertical Amplifier

Timebase Generators

Display Modes	Main timebase only, Main timebase intensified by delayed timebase, Delayed timebase.
Main (A) Timebase Speeds	0.2 μS/div to 0.2 S/div in 19 calibrated steps, 1-2-5 sequence. Continuously variable between steps.
Delayed (B) Timebase	0.2 μS/div to 0.5 mS/div in 11 calibrated steps, 1-2-5 sequence.
Maginifer	10X deflection increase at any timebase setting extends fastest sweep speeds of main and delayed timebases to 20 nS/div.
Accuracy	±3% normal, ±5% magnified
Delay Time	Continuously-variable multiplier with 1000 divisions. Accuracy approximately ±3%.
Delayed Timebase Jitter	1/10,000

Triggering

Sources	Channel 1, Channel 2, Alternate, Line, External
A Timebase Modes	Auto, Normal
B Timebase Modes	Immediate (after delay time) Triggered (after first trigger occuring after delay time)
Coupling	AC, HF reject, TV vertical, TV horizontal
Slope	+ or –
Holdoff	Normal, Variable to more than one sweep
Sensitivity (INT trigger)	30 Hz to 10 MHz: 0.5 div. 2 Hz to 50 MHz: 1.5 div.
Sensitivity (EXT trigger)	30 Hz to 10 MHz: 0.2 V p-p 2 Hz to 50 MHz: 0.6 V p-p
Auto Trigger Cutoff	30 Hz for above sensitivities
Input Impedance	1 megohm, 20 pF
Maximum Input Voltage	600 V (DC plus AC peak)

Calibrator

Output Voltage	500 mV p-p ±2%, positive-going, ground reference
Frequency	Approximately 1 kHz
Waveform	Fast-rise square wave

Z-Axis Modulation

Level for Blanking	TTL compatable
Coupling	DC
Input Impedance	22 k-ohms
Bandwidth	1 MHz
Maximum Input Voltage	50 V (DC plus AC peak)

CRT Display

Type	150BYB31 6-inch PDA
Phosphor	P31
Accelerating Potential	12 kV
Graticule	Internal 1 cm square divisions, 8 divs high, 10 divs wide. Central axes subdivided into 0.2 cm graduations.
Graticule Illumination	Continuously variable

Physical & Environmental Data

Size (W x H x D)	11 1/2 x 6 3/8 x 14 3/4 inches 290 x 160 x 375 mm
Weight	16.5 lbs, 7.5 kG
Ambient Operating	15°C-35°C (59°F-95°F)

Power Requirements

Line Voltage	90–132 VAC, 198–264 VAC
Line Frequency	50–60 Hz
Power Consumption	55 W

Supplied Accessories

Instruction Manual
Two (2) type LP-050X probes
Two (2) BNC to banana plug adapters
Spare fuse

Table 1-2

LP-050X SPECIFICATIONS

10X Position	
Input Impedance	10 megohms in parallel with 25pF
Voltage Division Ratio	10:1 ±2%
Bandwidth	DC-50 MHz
Maximum Input Voltage	600 V (DC plus AC peak)

1X Position	
Input Impedance	1 megohm (scope input resistance) in parallel with approximately 250 pF (combined probe and scope capacitance)
Bandwidth	DC-5 MHz
Maximum Input Voltage	600 V (DC plus AC peak)

2. OPERATING INSTRUCTIONS

This section contains the information required to operate the LBO-525L and utilize it in a variety of basic and advanced measurement procedures. Included are the identification and function of controls, connectors, and indicators, startup procedures, basic operating routines,

2-1. FUNCTION OF CONTROLS, CONNECTORS, AND INDICATORS

Before turning on this instrument, familiarize yourself with the controls, connectors, indicators, and other features described in this section. The following descriptions are keyed to the items called out in Figures 2-1 to 2-4.

2-1-1 Display Block

Refering to Figure 2-1 for reference (1) to (8).

(1) CAL connector	Provides fast-rise square wave of precise amplitude for probe compensation and vertical amplifier calibration.
(2) INTEN control	To adjust the brightness of the CRT display. Clockwise rotation increases brightness.
(3) FOCUS control	To attain maximum sharpness.
(4) ROTATION control	Provides screwdriver adjustment of trace alignment with regard to the horizontal CRT graticule lines.

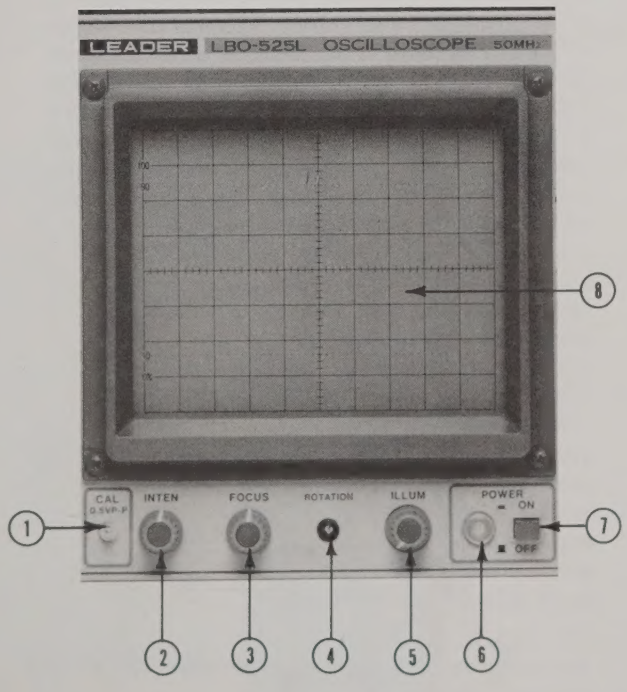


Figure 2-1. Display block

(5)	ILLUM control	To adjust graticule illumination. Clockwise rotation increases brightness.
(6)	POWER lamp	Lights when instrument power is on.
(7)	POWER switch	Depress to turn instrument power on and off.
(8)	CRT	Display device having 1 cm square graticule lines inscribed on the inner CRT surface for parallax-free measurements. Blue filter provides good contrast and pleasing display.

2-1-2 Vertical Amplifier Block

Refer to Figure 2-2 for reference (9) to (18), and Figure 2-4 for reference (19).

(9)	CH-1 or X-IN connector	For applying an input signal to vertical-amplifier channel 1, or the X-axis (horizontal) amplifier during X-Y operation.
(10)	Ch-2 or Y-IN connector	For applying an input signal to vertical-amplifier channel 2, or the Y-axis (vertical) amplifier during X-Y operation.
(11)	VOLTS/DIV switches	To select the calibrated deflection factor of the input signals fed to the vertical amplifiers.
(12)	VARIABLE/ PULL X10 MAG/ controls	Provide continuously-variable adjustment of deflection factor between steps of the VOLTS/ DIV switches. VOLTS/DIV calibrations are accurate only when the VARIABLE controls are click-stopped in their fully clockwise positions.

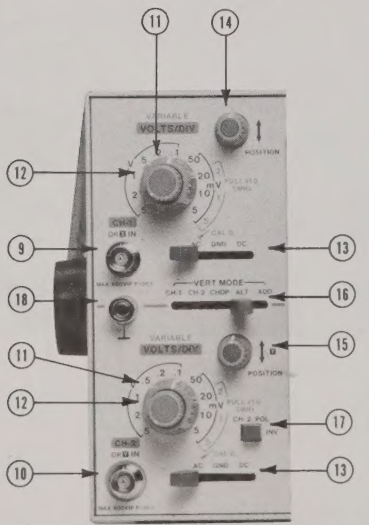


Figure 2-2. Vertical amplifier block

Pulling this switch out will increase the sensititivity of the associated vertical amplifiers by a factor of ten over a reduced bandwidth of DC-5 MHz. When pulled out, the 5 mV, 10 mV and 20 mV/div. positions of the associated VOLTS/DIV switches become 500 μV, 1 mV and 2 mV/div. respectively.

(13)	AC/GND/DC	To select the method of coupling the input signals to the vertical amplifiers. AC position connects a capacitor between the input connector and its associated amplifier circuitry to block any DC component in the input signal. GND position connects the amplifier input to ground instead of the input connector, so a ground reference can be established. DC position connects the amplifier inputs directly to the associated input connector, thereby passing all signal components on to the amplifiers.
(14)	CH-1 Vertical POSITION Control	For vertically positioning trace 1 on the CRT screen. Clockwise rotation moves the trace up. Inoperative during X–Y operation.
(15)	CH-2 Vertical or Y POSITION Control	For vertically positioning trace 2 on the CRT screen. Clockwise rotation moves the trace up. Adjusts the Y axis of the trace during X-Y operation.
(16)	VERT MODE	To select the vertical-amplifier display mode. Ch-1 position displays only the channel 1 input signal on the CRT. Ch-2 position displays only the channel 2 input signal on the CRT. CHOP position displays the input signals of both channels 1 and 2. The CRT beam is switched between channels at a

250 kHz rate during the horizontal sweep to achieve this multi-channel display.

ALT position displays the input signals of both channels 1 and 2. The CRT beam is switched between channels at the end of each sweep to achieve this multi-channel display.

ADD position displays a single trace that is the algebraic sum of the channel 1 and channel 2 input signals. This results in a differential display if the CH-2 POL switch is set to INV.

(17) **CH-2 POL switch** — Inverts the polarity of the channel 2 signal when depressed.

(18) **Ground connector** — Provides a convenient point to attach a separate ground lead to the oscilloscope.

(19) **CH-1 OUTPUT connector** — Provides amplified output of the channel 1 signal suitable for driving a frequency counter or other instrument.

2-1-3 Sweep and Trigger Block

Refer to Figure 2-3 for references (20) to (33).

(20) **A TIME/DIV and DELAY TIME switch** — To select either the calibrated sweep rate of the main (A) timebase, the delay time range for delayed-sweep operation, or X-Y operation.

(21) **B TIME/DIV switch** — To select the calibrated sweep rate of the delayed (B) timebase.

(22) **TIME VARIABLE control** — Provide continuously-variable adjustment of sweep rate between steps of the A TIME/DIV switch. TIME/DIV calibrations are accurate only when the TIME VARIABLE control is click-stopped in its fully clockwise position.

(23) **DELAY TIME control** — To determine the exact starting point within the A time base delay range at which the B timebase will begin sweeping. The absolute delay time is equal to the sweep time rate (A TIME/DIV) multiplied by the DELAY TIME.

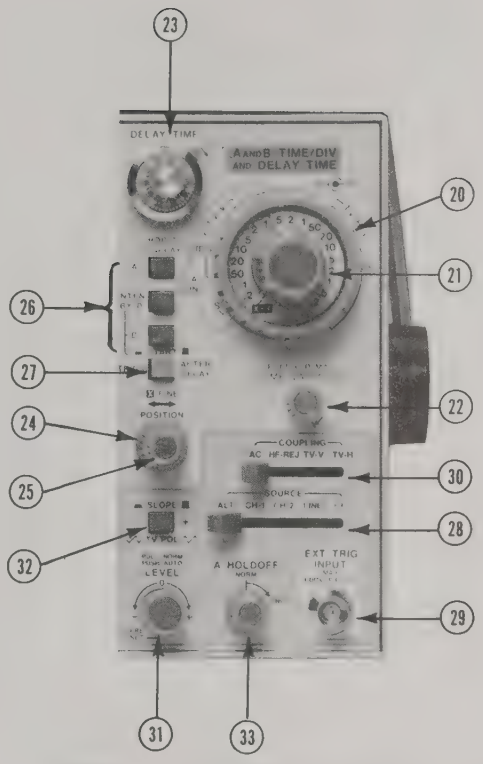


Figure 2-3. Sweep and trigger block

(22) **PULL X10 MAG/ TIME VARIABLE control** — Provides continuously-variable adjustment of sweep rate between steps of the TIME/DIV switches. TIME/DIV calibrations are accurate only when the VARIABLE control is detented in it's fully clockwise position. Pulling the control out expands the horizontal deflection by 10 times thus increasing horizontal sensitivity by 10 times for X-Y operation. The effective timebase sweep rate is also increased by 10 times, making 20 nS per division the highest sweep rate available.

(24) **Horizontal POSITION control** — To adjust the horizontal position of the traces displayed on the CRT. Clockwise rotation moves the trace(s) to the right. During X-Y operation, this control must be used for X-axis positioning.

(25) **X FINE control** — To adjust the horizontal position of the CRT traces as described above, but has less effect per degree of rotation. This facilitates precise positioning when X10 magnification is used.

(26) HORIZ DISPLAY sweep

To select the sweep mode.

A push-button sweeps the CRT at the main (A) time-base rate when pressed.

INTEN BY B push-button sweeps the CRT at the main (A) time-base rate when pressed, and the delayed (B) time-base intensifies a section of the trace(s). The location of the intensified section is determined by the DELAY TIME multiplier control, and under some circumstances also by the START switch. B push-button sweeps the CRT at the rate selected by the B TIME/DIV switch, after a delay determined by the A TIME/DIV switch and DELAY TIME multiplier control. The trace displayed over the full CRT graticule width corresponds to the intensified section of trace displayed during INTEN BY B operation.

(27) START switch

To select the starting time of the B sweep.

AFTER DELAY position (pushbutton out) causes the B sweep to begin immediately after the delay time (determined by the A TIME/DIV switch and DELAY TIME multiplier.

TRIG'D position (pushbutton in) causes the B sweep to be triggered by the first trigger pulse occuring *after* the delay time. The effective delay time is adjustable only in whole increment of the time between trigger points.

(28) SOURCE switch

To select the signal used for time-base triggering.

ALT position selects a triggering mode that allows a stable display of two asynchronous signals on the CRT.

CH-1 position selects the channel 1 signal for triggering.

CH-2 position selects the channel 1 signal for triggering.

Line position selects a trigger signal derived from the AC power line, permitting the scope to display stablized line-related components of a signal even though they may be very small compared to other signal components.

EXT position selects the signal applied to the EXT TRIG IN connector.

(29) EXT TRIG IN connector

For applying an external signal to the oscilloscope for triggering.

(30) COUPLING switch

To select the method of coupling the input signals to the vertical amplifiers.

AC position has a large capacitor in the trigger-coupling chain to remove any DC components from the trigger signal. AC signals below 2 Hz are also attenuated, as is the case in all of the trigger-coupling modes listed below.

HF-REJ position inserts a filter in the trigger-coupling chain that removes signal components higher in frequency than 100 kHz.

TV-V position inserts a shaping filter (TV sync separator) whose low-frequency output (vertical sync pulses) is used for triggering.

TV-H position inserts a shaping filter (TV sync separator) whose high-frequency output (horizontal sync pulses) is used for triggering.

(31) PULL NORM/ PUSH AUTO switch (on LEVEL control)

To select the triggering mode. When depressed, sweep free runs and a baseline is displayed in the absence of signal. Automatically switches to triggered sweep when a signal of 30 Hz or higher is present and other trigger controls are properly set.

When pulled, sweep occurs only when a trigger signal is present and other controls are properly set. No trace is visible if any trigger requirement is missing.

(31) **LEVEL control** — To select the trigger-signal amplitude at which triggering occurs. When rotated clockwise, the trigger point moves toward the positive peak of the trigger signal. When this control is rotated counterclockwise, the trigger point moves towards the negative peak of the trigger signal.

(32) **SLOPE switch** — To select the positive or negative slope of the trigger signal for initiating sweep.

(33) **A HOLDOFF control** — Allows triggering on complex signals by changing the blanked sweep retrace time of the main (A) sweep. This prevents triggering on intermediate trigger points within the repetition cycle of the desired display. The holdoff time is increased with clockwise rotation.

2-1-4 Miscellaneous

Refer to Figure 2-4 for references (34) to (42).

(34) **Z AXIS INPUT connector** — For applying TTL compatable signal to intensity modulate the CRT

(35) **FUSE** — Receptacle permits quick fuse replacement without opening case. Insert No. 2 Philips screwdriver in cross slot and rotate CCW to remove cap and fuse. When replacing fuse, ensure that its rating matches that shown on the VOLTAGE Chart.

(36) **Power cord** — For applying power to the instrument.

(37) **VOLTAGE chart** — Indicates the power fuse rating and operating-voltage range for each voltage connection.

(38) **Cord Caddy** — Provides a quick method of securing the power cord, and supports the oscilloscope for vertical operation.

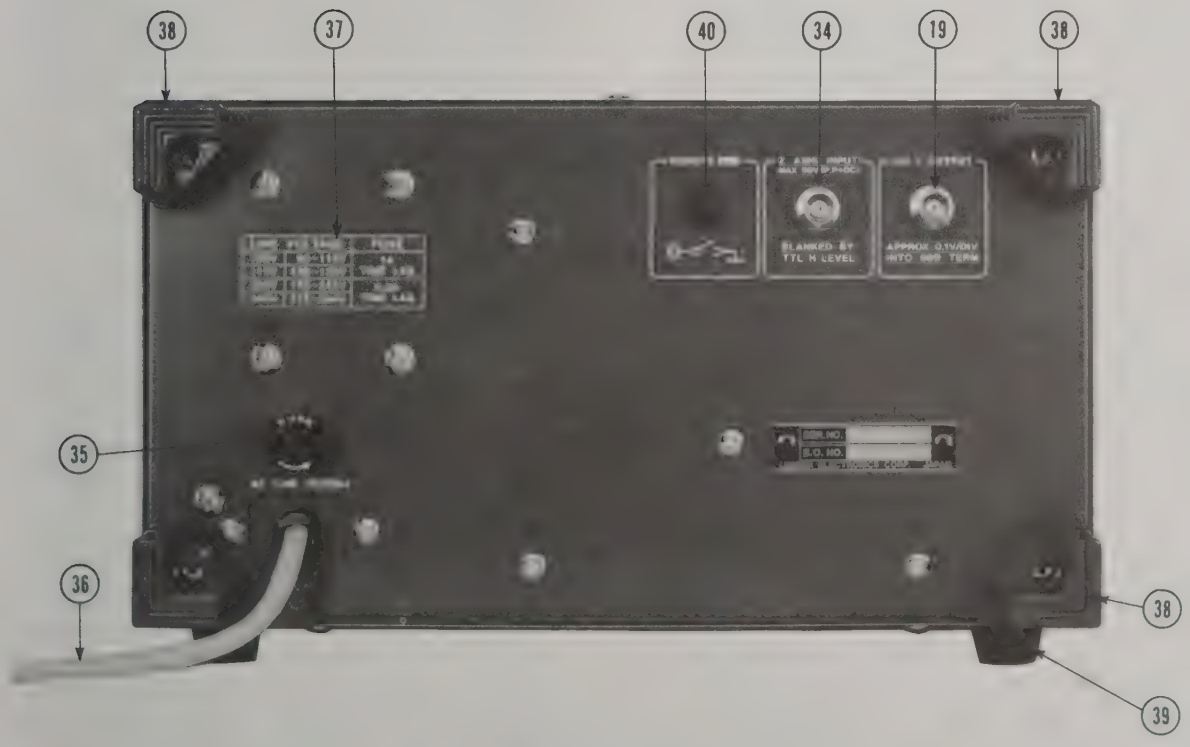


Figure 2-4. Rear panel and case feature.

(39)	Feet	Support the oscilloscope for shelf mounting.
(40)	REMOTE X-Y port	Allows physical access to CRT deflection-plate pins.

2-2 Initial Operation

Before the instrument is operated for the first time, perform the following procedures *in the order listed* to ensure proper functioning and avoid damage.

2-2-1 Installation

The LBO-525L will operate in either a horizontal or vertical position, making it highly suited to field or laboratory work. It can therefore be positioned on a bench top, riser shelf or even on the floor.

For bench-top mounting (Figure 2-5a), it is advantageous to have the front of the instrument tilted upward for straight-on viewing. Press in the two Handle-position Locks (41) and simultaneously rotate the Handle (40) so it points below the case, then release the locks.

If the instrument is placed on a riser shelf above the work bench (Figure 2-5b), rotate the Handle above the instrument and as far towards the back as possible. It is not necessary to lock it in this position.

If lack of working space requires that the instrument be placed on the floor (Figure 2-5c), stand the LBO-525L on end. The Cord Caddy (38) will act as legs to support the instrument. Rotate the Handle just far enough back for clear access to the front-panel controls.

The LBO-525L is designed to operate over a temperature range of 15°C to 34°C (59°F to 95°F) and a humidity range of 10 to 90%. Operation in a more severe environment may shorten the life of the instrument or result in out-of-spec performance.

Operation in a powerful magnetic field may distort the waveform or tilt the trace. This is most likely to occur if the instrument is operated close to equipment having large motors or power transformers and it is recommended that the instrument is not stored or operated in close proximity to this type of equipment.

2-2-2 Preliminary Control Settings and Adjustments

Before placing the instrument in use, set up and check the instrument as follows:

1. Set the following controls as indicated.

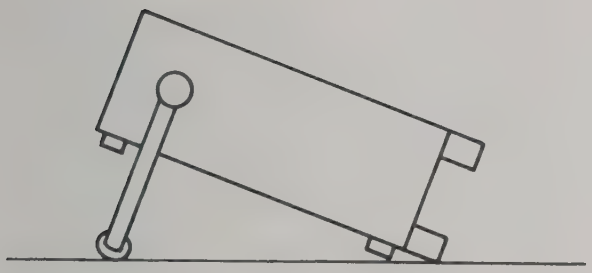
AC/GND/DC switches (13)	AC
VOLTS/DIV switches (11)	.2V
VARIABLE controls (12)	Fully CW
PULL X10 5 MHz switch (12)	Pushed in
VERT MODE switch (16)	ALT
Vertical POSITION controls (12) (15)	Index up
CH-2 POL switch (17)	Out
INTEN control (2)	Index up
FOCUS control (3)	Index up
ILLUM conrtol (5)	Fully CCW
A TIME/DIV switch (20)	.2 mS
TIME VARIABLE control (22)	Fully CW
PULL X10 MAG switch (22)	Pushed in
Horizontal POSITION control (24)	Index up
X FINE control (25)	Index up
HORIZ DISPLAY switches (26)	A
COUPLING switch (30)	AC
source switch (28)	CH-1
SLOPE switch (32)	Out
PULL NORM/PUSH AUTO switch (31)	Pushed in
LEVEL control (31)	Preset
A HOLDOFF control (33)	NORM

2. Plug the power cord into a convenient AC receptacle and flip up the POWER SWITCH (7). Shortly, two traces should appear. If the traces are *extremely* bright, turn the INTEN control (2) counterclockwise. Otherwise, allow the instrument to warm up for 10 to 20 minutes.

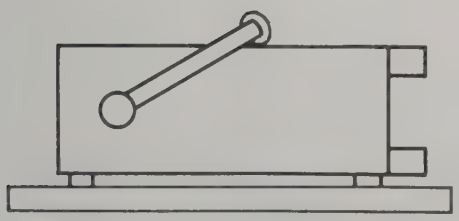
CAUTION

A burn-resistant fluorescent material is used in the CRT. However, if the CRT is left with an extremely bright dot or trace for a very long time, the fluorescent screen may be damaged. Therefore, if a measurement requires high brightness, be certain to turn down the INTEN control immediately afterward. Also, get in the habit of totally decreasing intensity turning the brightness way down if the scope is left unattended for any period of time.

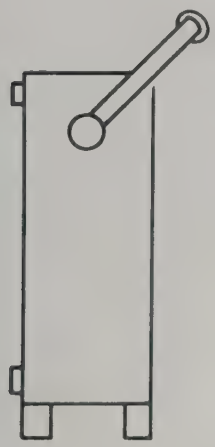
3. Turn the INTEN control to adjust the brightness to the desired level.
4. Turn the FOCUS control (3) for a sharp trace.
5. Turn the CH-1 Vertical POSITION control (14) to position the CH-1 trace two divisions down from the top of the graticule grid. Turn the CH-2 Vertical POSITION control (15) to position the CH-2 trace two divisions up from the bottom of the graticule grid.
6. The traces should be precisely parallel with the graticule lines. If they are not, adjust the ROTATION conrtol (4) with a small screwdriver for proper trace alignment.
7. Turn the Horizontal POSITION control (24) to align the left edge of the traces with the left-most graticule line.
8. Connect the CH-1 or X-IN (9) and CH-2 or Y-IN (10) connectors to the CAL connector (1) using the supplied probes. Two square-wave displays, each two and a half divisions in amplitude, should appear on the screen. If necessary, adjust the LEVEL control (31) for a stable display.
9. Disconnect the vertical inputs from the calibrator output.



A. Bench-top mounting



B. Shelf top mounting



C. Floor mounting

Figure 2-5. Handle positioning

2-3 BASIC OPERATING PROCEDURES

The following paragraphs in this section describe how to operate the LBO-525L, beginning with the most elementary operating modes, and progressing to the less frequently-used and/or more complex modes.

2-3-1 Signal Connections

There are three methods of connecting an oscilloscope to the signal you wish to observe. They are: a simple wire lead, coaxial cable, and scope probes.

A simple lead wire may be sufficient when the signal level is high and the source impedance low (such as TTL circuitry), but it is not often used. Unshielded wire picks up hum and noise; this distorts the observed signal when the signal when the signal level is low. Also, there is the problem of making secure mechanical connection to the input connectors. A binding post-to-BNC adapter (supplied accessory) is adviseable in this case.

Coaxial cable is the most popular method of connecting an oscilloscope to signal sources and equipment having output connectors. The outer conductor of the cable shields the central signal conductor from hum and noise pickup. These cables are usually fitted with BNC connectors on each end, and specialized cables and adaptors are readily available for mating with other types of connectors.

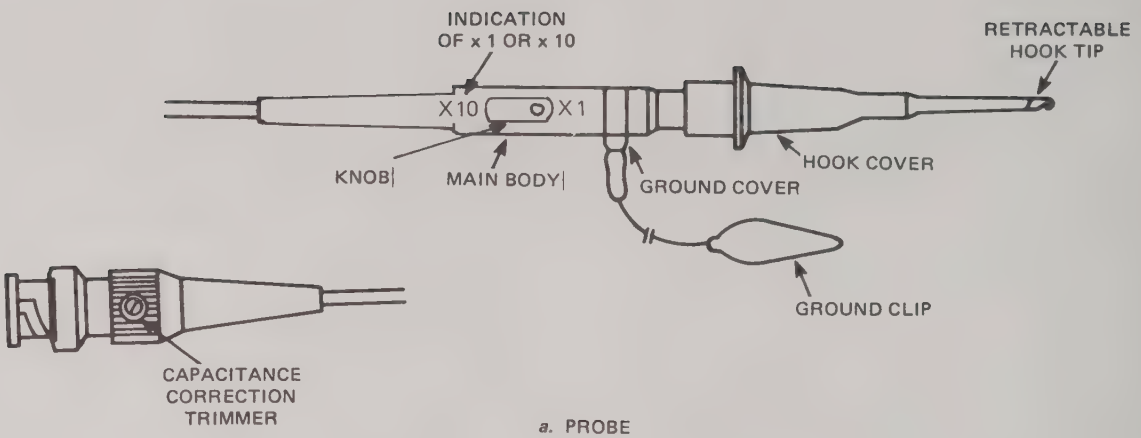
Scope probes are the most common method of connecting the oscilloscope to circuitry. These probes are available with 1X attenuation (direction connection). 10X and 100X attenuation. The 10X and 100X attenuator probes increase the effective input impedance of the probe/scope combination to 10 megohms shunted by a few picorafads. The reduction in input capacitance is the most important reason for using attenuator probes at high frequencies, where capacitance is the major factor in loading down a circuit and distorting the signal.

Despite their high input impedance, scope probes do not pickup appreciable hum or noise. As was the case with coaxial cable, the outer conductor of the probe cable shields the central signal conductor. Scope probes are also quite convenient from a mechanical standpoint. Quality probes have a spring-loaded hook end that quickly and securely holds the probe to wiring and component leads (see Figure 2-6). This hook can be removed to expose a straight tip, excellent for use on the non-component side pf a pc board or for quickly moving from one point to another.

To determine if a direct connection with shielded cable is permissible, you must know the source impedance of the circuit you are connecting to, the highest frequencies involved, and the capacitance of the cable. If any of these factors are unknown, use a 10X low-capacitance probe.

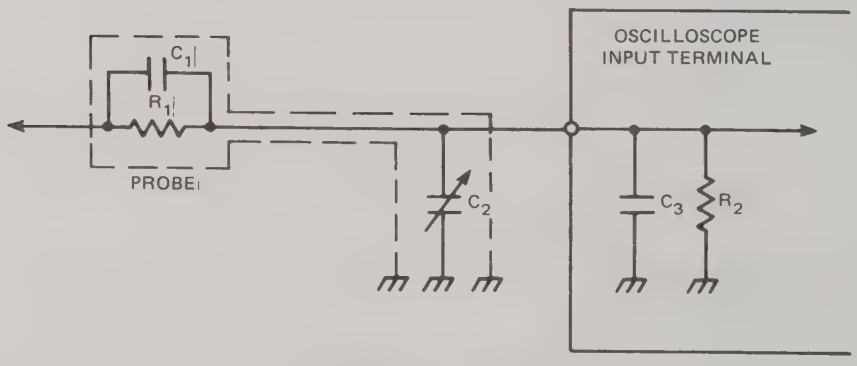
An alternative connection method at high frequencies is *terminated* coaxial cable. A feed-thru terminator having an impedance equal to that of the signal-source impedance is connected to the oscilloscope input connector. A coaxial cable of matching impedance connects the signal source to to the terminator. This technique allows using cables of nearly any practical length without signal loss.

If a low-resistance ground connection between oscilloscope and circuit is not established, enormous amounts of hum (noise) will appear in the display signal. Generally, the outer conductor of shielded cable provides the ground connection. If you are using plain lead wire, be certain to first connect a ground wire between the LBO-525L Ground connector (17) and the chassis or ground bus of the circuit under test.

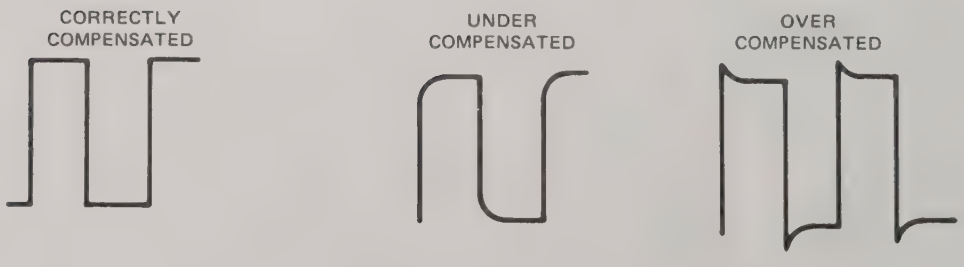


a. PROBE

b. PROBE CONVERSION TO STRAIGHT TIP



c. SCHEMATIC REPRESENTATION



d. EFFECTS OF PROBE COMPENSATION

Figure 2-6. Direct/Low Capacitance Probe LP-050X

WARNING

The LBO-525L has an earth-grounded chassis (via the 3-prong power cord). Be certain the device to which you connect the scope is transformer operated. Do Not connect this oscilloscope or any other test equipment to "AC/DC", "hot chassis", or "Transformerless" devices. Similarly, do NOT connect this scope directly to the AC power line or any other circuitry connected directly to the power line. Damage to the instrument and severe injury to the operator may result from failure to heed this warning.

2-3-2 Single-trace Operation

Single-trace operation with single timebase and internal triggering is the most elementary operating mode of the LBO-525L. Use this mode when you wish to observe only a single signal, and not be distracted by additional traces on the CRT. Since the LBO-525L is fundamentally a two-channel instrument, you have a choice for your single channel. Channel 1 has an output terminal; use channel 1 if you also want to measure frequency with an external counter while observing the waveform. Channel 2 has a polarity-inverting switch. While this adds flexibility, it is not used in ordinary single-trace operation.

The LBO-525L is set up for single-trace operation as follows:

1. Set the following controls as indicated below. Any controls not mentioned here or in the following steps can be negelected. Note that the trigger source selected (CH-1 or CH-2 SOURCE (28) must match the single channel selected (CH-1 or CH-2 VERT MODE (16)).

AC/GND/DC switches (13)	AC
PULL X10 5 MHz switches (12)	Pushed in
VARIABLE controls (12)	Fully CW
VERT MODE switch (16)	CH-1 (CH-2)
CH-2 POL switch (17)	Out
INTEN control (2)	APS*
FOCUS control (3)	APS*
POWER switch (7)	Pushed in
TIME VARIABLE control (22)	Fully CW
PULL X10 MAG switch (22)	Pushed in
Horizontal POSITION control (24)	APS*
X FINE control (25)	Index up
HORIZ DISPLAY switches (26)	A
COUPLING switch (30)	AC
SOURCE switch (28)	CH-1 (CH-2)
SLOPE switch (26)	+
PULL NORM/PUSH AUTO switch (31)	Depressed
LEVEL control (31)	PRESET
A HOLDOFF control (33)	NORM

*As previously set. Adjustment may occassionally be necessary to suit the circumstances.

2. Use the corresponding Vertical POSITION control (14) or (15) to set the trace to the center of the CRT.
3. Connect the signal to be observed to the corresponding Input connector (9) or (10), and adjust the corresponding VOLTS/DIV switch (11) so the signal is displayed on the CRT.

CAUTION

Do not apply a signal greater than 600V (DC + AC peak)

4. Set the A TIME/DIV switch (20) so the desired number of cycles of signal are displayed. For some measurements 50-100 cycles (appears like a solid band) works best. Adjust the LEVEL control (31) if necessary for a stable display.
5. If the signal you wish to observe is so weak that even the 5 mv position of the VOLTS/DIV switch cannot produce sufficient trace height for triggering or a useable display, pull the VARIABLE control (12) knob. This produces 2 mV/div sensitivity when the VOLTS/DIV switch is set to 20 mv, 1 mV/div when it is set to 10 mv, and .5 mV/div when it is set to 5 mV/div. However, the channel bandwidth decreases to 5 MHz, and may become noticeable when this is done.
6. If the signal you wish to observe is so high in frequency that even the .2 μS position of the A TIME/DIV switch results in too many cycles displayed, pull the TIME VARIABLE control (22) knob. This increases the effective sweep speed by a factor of 10, so .2 μS/div becomes 20 nS/div, .5 μs/div becomes 50 nS/div, etc. The 20 nS/div sweep speed achieveable by magnification is fast enough to display a single cycle of a 5 MHz signal across the CRT face.
7. If the signal you wish to observe is either DC or too low in frequency that AC cpoupling attenuates or distorts the signal, position the AC/GND/DC switch (13) to DC.

CAUTION

If the observed waveform is low-level AC, ensure that it is not imposed on a high-amplitude DC voltage.

2-3-3 Triggering Alternatives

Triggering is often the most difficult operation to perform on an oscilloscope because of the many options available and the particular requirements of certain signals. By using PRESET trigger level, AC coupling, and the AUTO sweep mode, error free triggering is obtainable with most signals. However, for complex or otherwise difficult signals, the LBO-525L operator may choose from a wide selection of trigger options. These categorized as trigger-source optionns, coupling options, trigger mode, and trigger-point selection.

Trigger Mode Selection. When the NORM trigger mode is not swept horizontally across the face of the CRT until a sample of the signal to be observed triggers the timebase. However, this trigger mode may sometimes be inconvenient

because the trace does not appear on the CRT screen in the absence of an input signal, or if the trigger controls are improperly set. Since the absence of the trace can also be due to an improperly-set vertical POSITION control or VOLTS/DIV switch, much time can be consumed determining the cause. The AUTO trigger mode solves this problem by causing the timebase to automatically free run when not triggered. This yields a single horizontal line with no signal, and a vertically-deflected but non-synchronized display when vertical signal is present but the trigger controls improperly set. This immediately indicates what is wrong. The only dissadvantage with AUTO operation is that signals below 30 Hz cannot, and complex signals of any frequency may not, reliably trigger the timebase. Therefore, the usual practice is to leave the PULL NORM/AUTO switch (31) depressed, but pull for NORM if any signal (particularly one below 30 Hz) fails to produce a stable display.

Trigger Source Options. Trigger signal can be obtained from the signal applied to the vertical inputs, or from a separate source of the same or a harmonically-related frequency. The SOURCE switch (28) offers several choices.

The CH-1 and CH-2 positions offer a choice of one of the two input channels as the trigger source. The choice of channels remains even if the trigger channel is not displayed; the only requirement is that signal be applied to the trigger-source channel and the associated VOLTS/DIV switch be set to provide sufficient signal amplitude. The minimum trigger amplitude is approximately half a major division below 10 MHz, and increases to 1-1/2 major divisions at 50 MHz. If possible, use at least a full division below 10MHz, and two divisions above 10 MHz.

If both channels are displayed, and the two signals are different but harmonically-related frequencies, trigger from the lowest-frequency channel if possible. This will ensure that both traces are stable.

Select the ALT position when you want to display *two* signals *not* harmonically related to each other (720 Hz and 939 Hz, for example).

NOTE

The VERT MODE switch (16) must always be set to ALT when the SOURCE switch is set to ALT.

The line position provides trigger signal at the local power line frequency. This is a valuable function when observing a low-level ripple component imposed on a large DC voltage, or within a mixture of other AC voltages. The line-frequency trigger will sync a signal at any reasonable multiple of the power-line frequency.

The EXT position uses whatever signal is applied to the EXT TRIG INPUT connector (29) as the trigger source.

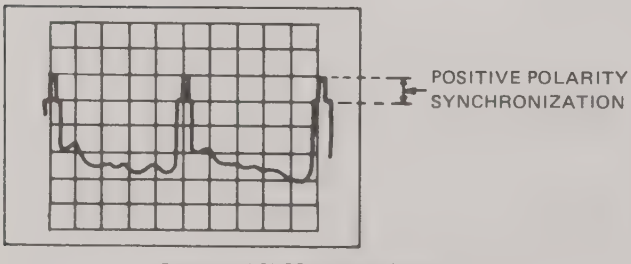
CAUTION

Do not apply a signal greater than 600V (DC plus AC peak). Further, use a 0.022 μF blocking capacitor in series with this input if the trigger signal consists of a small AC signal imposed on a large DC level.

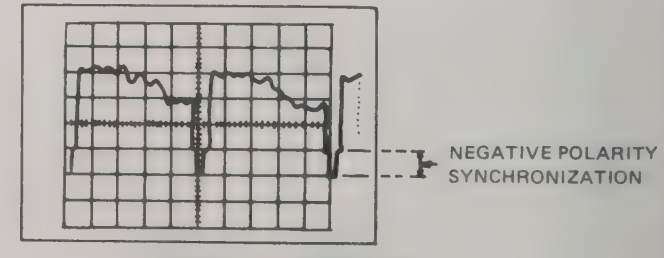
Using any trigger source *not* derived from the channel you are watching has the advantage that changes in the amplitude of the signal under observation (either directly or by resetting the VOLTS/DIV switch) will not cause the display to lose sync, even if the amplitude of the observed signal falls below a screen division. External trigger has the advantage that complex and/or noisy signals can be stably displayed as long as the trigger signal is free from noise.

Trigger Coupling Options. The various trigger coupling options for the main (A) timebase increase the probability of stable triggering on extremely complex signals, such as those containing several frequencies and/or hum and noise.

The COUPLING switch (30) inserts frequency-selective filters that pass certain frequencies on to the trigger circuitry and reject others. The AC position removes any DC component in the trigger signal. This assures that all signals have a zero crossing and will usually trigger the scope with PRESET trigger level. Use AC coupling for most signals.



a. Position of SLOPE Switch (38): +

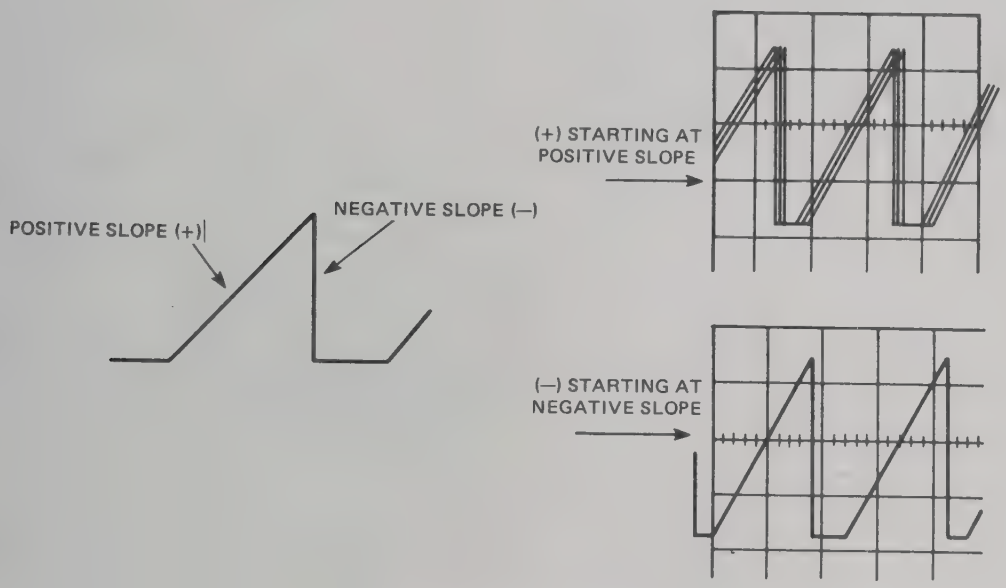


b. Position of SLOPE Switch (38): –

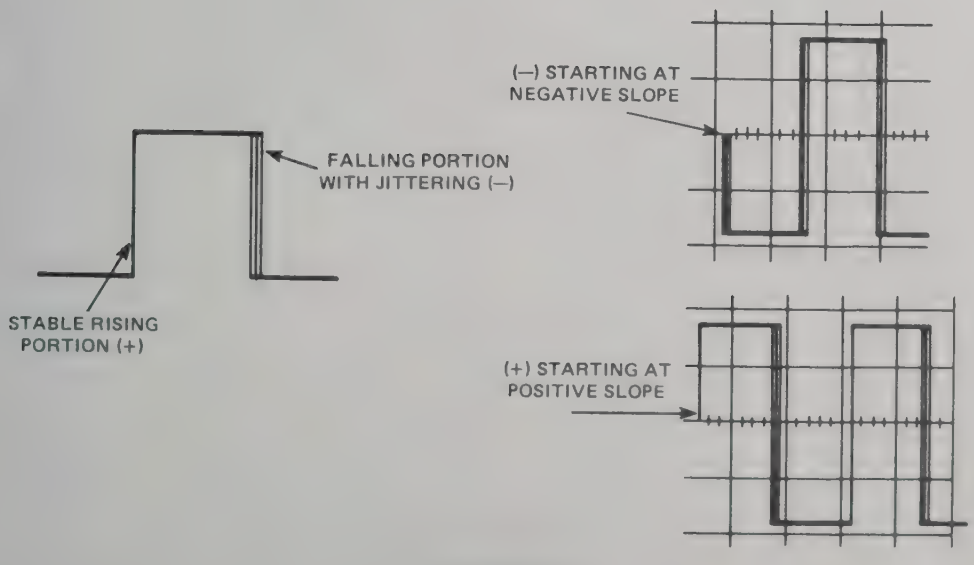
Figure 2-7. Selection of SLOPE Switch Position for TV Signals

The HF-REJ pushbutton cuts off frequencies higher than 100 kHz, passing only signals in the 2 Hz to 20 kHz region. Use this position if high-frequency noise (the CHOP switching pulses for example) is mixed with a low-freqency signal.

The TV-V and TV-H positions insert a TV sync separator into the trigger circuit, so a clear trigger signal at either the vertical or horizontal repetition rates can be removed from a composite video signal. The TV-V pushbutton is also effective in securing stable triggering at the low frequency (60 or 70 Hz) of an audio intermodulation distortion test signal. To trigger the scope at the vertical (frame) rate, press the TV-V pushbutton. To trigger the scope at the horizontal (line) rate, press the TV-H pushbutton. When either of the TV pushbuttons are used, the SCOPE switch (32) must be matched to the polarity of the video signal. Leave the SLOPE pushbutton out (+ position) for positive-sync signals (Figure 2-7A), and depresses (—position) for negative-sync video signals (Figure 2-7B).



a. SAWTOOTH WAVEFORM



b. SQUARE WAVE

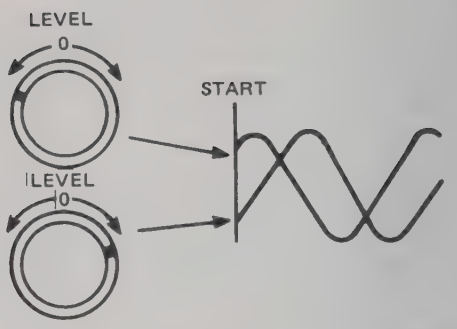
Figure 2-8. SLOPE Switch Setting

Trigger Point Selection. For a stable display, the timebase must be triggered at the exact same point on the recurrent waveform each time the timebase is swept. This is sometimes difficult so the LBO-525L has three controls that enable the operator to achieve this condition. They are the LEVEL control (31), the SLOPE switch (32), and the A HOLDOFF control (33).

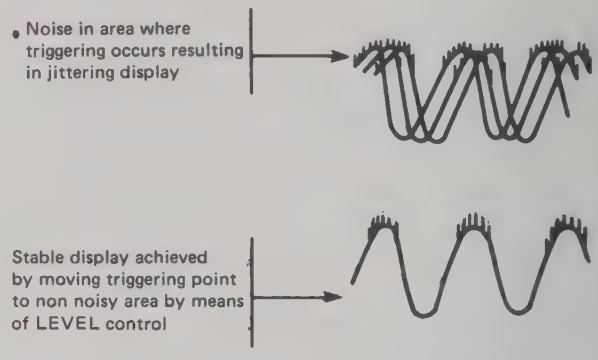
The SLOPE switch determines whether the sweep will begin on a positive-going or negative-going slope of the trigger signal (see Figure 2-8). In some cases the choice of slope is unimportant, in others it is vitally important to attain a stable and/or jitter-free display. Always select the steepest and most stable slope or edge. For example, small changes in the amplitude of the sawtooth shown in Figure 2-8A will cause jittering if the timebase is triggered on the positive (ramp) slope, but have no effect if triggering occurs on the negative slope (a fast-fall edge). In the example shown in Figure 2-8B, both leading and trailing edges are very steep (fast rise and fall times). However, this particular pulse is the output of a leading-edge triggered monostable, and has inherent pulse-width jitter. Triggering from the jittering trailing edge will cause the entire trace to jitter, making observation difficult. Triggering from the stable leading edge (+ slope) yields a trace that has only the trailing-edge jitter of the original signal. If you are ever in doubt, or have an unsatisfactory display, try both slope settings to obtain the optimum display.

The LEVEL control determines the point on the selected slope at which the main (A) timebase will be triggered. The effect of the LEVEL control on the displayed trace is shown in Figure 2-9A. The 0, +. and – panel markings for this control refer to the waveform's center crossing and points on the waveform more positive (+) and more negative (–) than this. If the trigger slope is very steep, as with square waves or digital pulses, there will be no apparent change in the displayed trace until the LEVEL control is rotated past the most positive or most negative trigger point, whereupon the display will free run (AUTO sweep mode) or disappear completely (NORM sweep mode). Try to trigger at the mid point of slow-rise waveforms (such as sine and triangular waveforms), since these are usually the areas on such waveforms with the lowest noise level. As Figure 2-9B shows, triggering on a noisy area will cause instability in the display. Rotating the LEVEL control fully counter-clockwise to the detented PRESET position automatically triggers the timebase close to the zero-crossing point of the trigger signal. This corresponds to the midpoint for symmetrical waveform such as sine waves, triangle waves, square waves, etc. Unipolar signals (such as TTL, CMOS, or ECL pulses) have no zero crossing; however, AC coupling adds a zero crossing. This "method" works best for waveforms whose duty cycles are near 50%; it will not work with very low (10% or less) or very high (90% or more duty cycles.) Manual adjustment of the LEVEL control may therefore be necessary with some signals.

The larger the amplitude of the trigger signal *inputted* to the trigger circuits, the greater is the degree of rotation



a. Effect of LEVEL Control Adjustment on Triggering Starting Position


Noise in area where triggering occurs resulting in jittering display
Stable display achieved by moving triggering point to non noisy area by means of LEVEL control

b. Elimination of Jittering Display by LEVEL Control Adjustment

Figure 2-9. LEVEL Control Adjustment

(control range) over which the LEVEL control will maintain a stable display. With internally-derived trigger, the actual trigger amplitude is proportional to the number of graticule divisions occupied by the trace. Therefore, the trigger point is more critical with small signals than large. This is one reason why it is important to use as much trace height as practical for the number of traces displayed.

The A HOLDOFF control is used for special circumstances only. It allows the operator to adjust the mandatory sweep retrace time between the end of one sweep and the start of the next (in response to a trigger pulse). This prevents the triggering of subsequent sweeps by the wrong trigger pulse in a complex waveform. During the normal operation, leave the A HOLDOFF control detented at NORM. When viewing complex waveforms containing multiple trigger points per repetition, rotate the A HOLDOFF control clockwise until the proper waveform is secured, as shown in Figure 2-10. For example, the waveform shown contains three pulses in each group capable of triggering the timebase, but sweep must begin only on the first pulse in each burst to obtain the proper display. In the lower display, the sweep retrace time has been extended enough to make it impossible for the last pulse in in the second burst to start the next sweep.

2-3-4 Probe Compensation and Use

The LP-050X probes furnished with the LBO-525L can be set for either low-capacitance operation (10X attenuation) or direct connection (1X attenuation). The selection is made by rotating the collar at the end of the probes main body (see Figure 2-6A) 1/2 turn. The appearance of a new attenuation indication as the collar click-stops into position indicates the conversion is completed.

At either attenuation setting you have a choice of spring-loaded hook tip or straight tip (see Figure 2-6B). The hook tip is for "hands off" connections to wiring, components, or test points. Pull back the flange on the hook cover to expose the hook to permit attachment. Releasing the flange secures the hook to the circuit under observation. To expose the needle tip, unscrew the hook cover as shown.

When 1X attenuation is selected, the probe simply operates as a section of a shielded cable. The signal source "senses" the 1 megohm input resistance of the LBO-525L in parallel with 35 pF input capacitance *and* the 200 pF or so cable capacitance of the probe. Because of this capacitance, 1X attenuation is generally used only at low frequencies and/or with low-impedance signal sources. Although many conditions (source impedance, source capacitance, frequency, allowable error, etc.) are factors in attenuation choice, the impedance and frequency limits beyond which 1X operation of the LP-050X should generally be avoided are 1 MHz with 50-ohm sources, and 50 kHz with 1000-ohm sources.

When 10X attenuation is selected, the probe forms a compensated voltage divider (see Figure 2-6C) that has a constant division ratio at all frequencies. Moreover, the signal sources "senses" only a fraction of the cable capacitance (about 25 pF), so error-causing capacitance loading of high impedance sources is greatly reduced. Because of this, 10X probes are used for measurements and waveform observation much more than any other connecting device. Note however, that the probes must be properly adjusted or "compensated" to achieve the error-reducing benefits of 1X attenuation. To do this, proceed as follows:

1. Connect a probe to the CH-1 or X-IN connector (9) and the CAL connector (1).

NOTE

For best results, connect the probe ground lead to the other channel's input connector or the Ground connector (18).

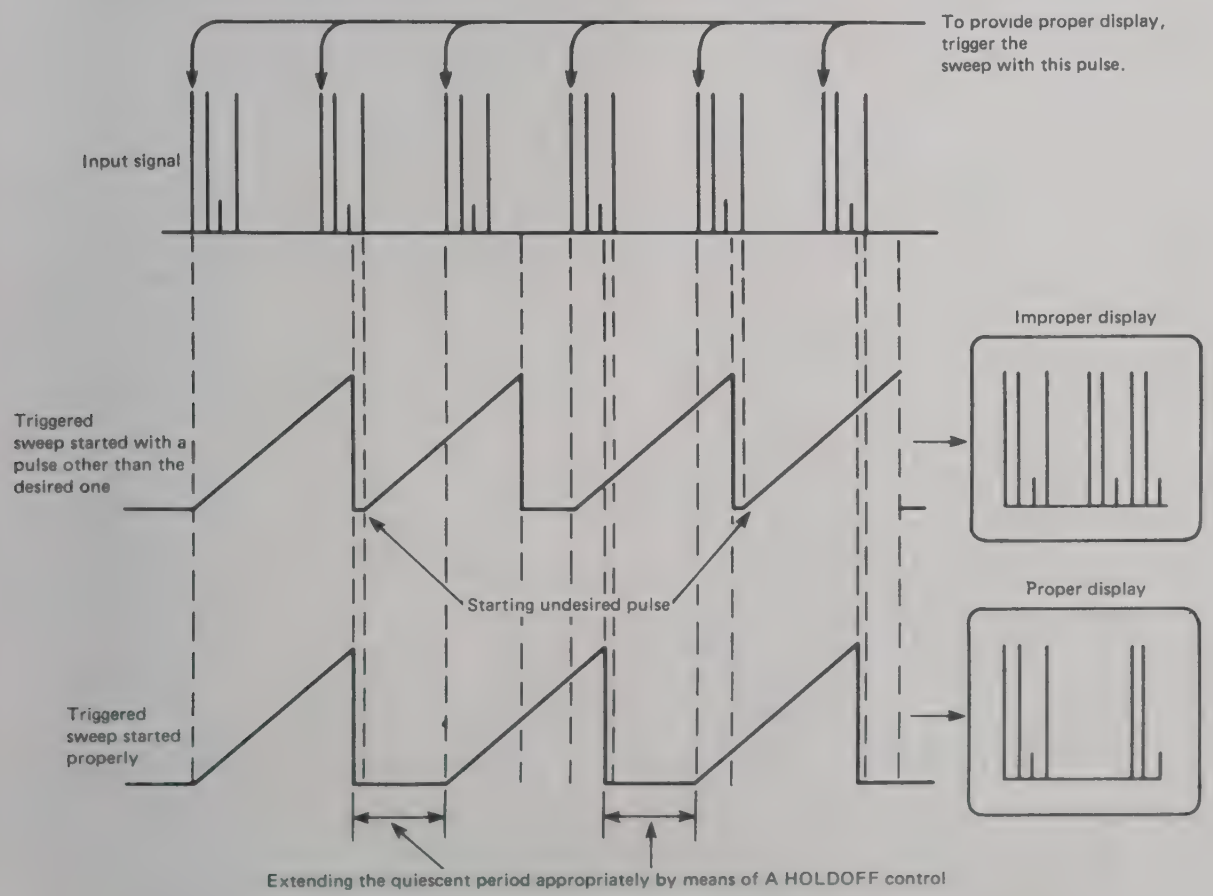

To provide proper display, trigger the sweep with this pulse.
Input signal
Improper display
Triggered sweep started with a pulse other than the desired one
Starting undesired pulse
Proper display
Triggered sweep started properly
Extending the quiescent period appropriately by means of A HOLDOFF control

Figure 2-10. A HOLDOFF Control Adjustment

2. Set the VOLTS/DIV switches (11) to 20 mV, and the A TIME/DIV switch (20) to .2 mS.
3. Set the VERT MODE switch (16) to CH-1, and the SOURCE switch (28) to CH-1.
4. With a small screwdriver, adjust the capacitance-correction trimmer (Figure 2-6A) for a correctly-compensated square wave (Figure 2-6D).
5. Set the VERT MODE switch to CH-2, the SOURCE switch to CH-2, and perform Steps 1, 2, and 4 for channel 2 with the other probe.

2-3-5 Dual-trace Operation

Dual-trace operation is the major operating mode of the LBO-525L. As was the case with *Single-trace Operation*, you have a choice here too; not of channel selection, but of how to display the two channels.

The LBO-525L is set up for dual-trace operation as follows:

1. Set the following controls as indicated below. Any controls not mentioned here or in the following steps can neglected.

AC/GND/DC switches (13)	AC
PULL X10 5 MHz switches (12)	Pushed in
VARIABLE controls (12)	Fully CW
CH-2 POL switch (17)	Out
INTEN control (2)	APS*
FOCUS control (3)	APS*
POWER switch (7)	Pushed in
TIME VARIABLE control (22)	Fully CW
PULL X10 MAG switch (22)	Pushed in
Horizontial POSITION control (24)	APS*
X FINE control (25)	Index up
HORIZ DISPLAY switches (26)	A
COUPLING switch (30)	AC
SLOPE switch (32)	+
PULL NORM/PUSH AUTO switch (31)	Pushed in
LEVEL control (31)	PRESET
A HOLDOFF control (33)	NORM

*As previously set. Adjustment may occassionally be necessary to suit the circumstances.

2. Select either the ALT or CHOP position of the VERT MODE switch (16). Select ALT for relatively high-frequency displays (A TIME/DIV switch (20) to be set at .2 ms or faster); select CHOP for relatively low-frequency displays (A TIME/DIV switch to be set at .5 ms or slower). If the CHOP position is selected when fast sweep speeds are used, the displayed trace will appear broken (as in Figure 2-11) when signals are applied. If the ALT position is selected when slow speeds are used, the display will flicker excessively.
3. Use the vertical POSITION controls (14) and (15) to set the CH-1 trace about two divisions down from the top graticule line, and the CH-2 trace about two divisions up from the bottom graticule line.
4. Connect the signals to be observed to the CH-1 and CH-2 Input connectors (9) and (10), and adjust the VOLTS/DIV switches (11) so the displayed signals are totally on screen and clear of each other.

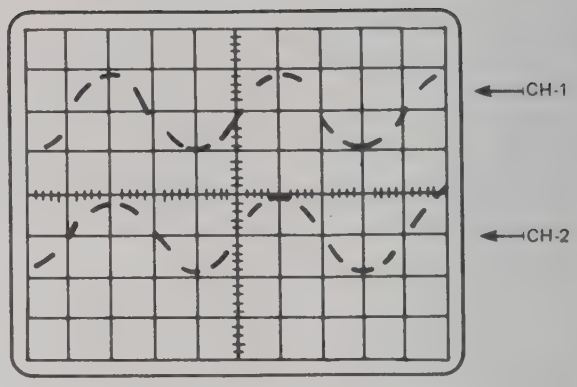


Figure 2-11. CHOP display at sweep speeds above 0.5 mS/div

CAUTION

Do not apply signals greater than 600V (DC + AC peak).

5. Set the A TIME/DIV switch so the desired number of cycles are displayed. For some measurements just 2 or 3 cycles are best; for other measurements 50–100 cycles (appearing like a solid band) works best. Be certain the display mode (ALT or CHOP) selected is consistant with this sweep speed (as per Step 2). Adjust the LEVEL control (31), if necessary, for a stable display.
6. If both channels are displaying signals of the same frequency, trigger from the channel having the steepest-slope waveform. If the signals are different but harmonically-related frequencies, trigger from the channel carrying the lowest frequency. Also, bear in mind that if you disconnect the signal to the channel serving as the trigger source, the entire display will free run.
7. If the signals are different frequencies are *not* harmonically related, select the ALT position of the SOURCE switch (28) and set the VERT MODE switch (16) at ALT regardless of the A TIME/DIV switch setting.
8. If a signal you wish to observe is so low in amplitude that even the 5 mV position of the VOLTS/DIV switch cannot produce sufficent trace for triggering for a stable display, pull the VARIABLE control (12) knob. This produces 2 mV/div sensitivity when the VOLTS/DIV switch is set to 20 mV, 1 mV/div when it is set to 10 mV, and .5 mV/div when it is set to 5 mV/div. However, the channel bandwidth decreases to 5 MHz, and the inherent trace noice becomes noticeable when this is done.
9. If the signal you wish to observe is so high in frequency that even the .2 μS position of the A TIME/DIV switch results in too many cycles displayed, pull the TIME VARIABLE control (22) knob. This increases the effective sweep speed by a factor of 10, so .2 μS/div becomes 20 nS/div, .5 μS/div becomes 50 nS/div, etc. The 20 nS/div sweep speed achieveable by magnification

is fast enough to display a single cycle of a 5 MHz signal across the CRT face.

10. If the signal you wish to observe is either DC or low enough in frequency that AC coupling attenuates or distorts the signal, set the AC/GND/DC switch (13) to DC.

CAUTION

If the observed waveform is low-level AC, make certain it is not imposed on a high-amplitude DC voltage.

2-3-6 Additive and Differential Operation

Additive and differential operation are forms of two-channel operation where two signals are combined to display one trace. In additive operation, the resultant trace represents the algebraic *sum* of the CH-1 and CH-2 signals. In differential operation, the resultant trace represents the algebraic *difference* between the CH-1 and CH-2 signals.

To set up the LBO-525L for additive operation, proceed as follows:

1. Set up the dual-trace operation per paragraph 2-3-5, Steps 1 to 6 and 8 to 10.
2. Make sure both VOLTS/DIV switches (11) are set to the same position; and the VARIABLE controls (12) are click-stopped in their CAL'D position. If the signal levels are very different, set both VOLTS/DIV switches to the position producing a large on-screen display of the *high-amplitude* signal.
3. Trigger from the channel having the highest-amplitude signal.
4. Set the VERT MODE (16) switch to ADD. The single trace resulting is the algebraic sum of the CH-1 and CH-2 signals. Either or both of the Vertical POSITION controls (14) and (15) can be used to shift the resultant trace.

NOTE

If the input signals are in-phase, the amplitude of the resultant trace will be the arithmetic sum of the individual traces (e.g., 4.2 div + 1.2 div = 5.4 div). If the input signals are 180° out of phase, the amplitude of the resultant trace will be the arithmetic difference of the two traces (e.g., 4.2 div -1.2 div = 3.0 div).

5. If the peak-to-peak amplitude of the resultant trace is very low, turn *both* VOLTS/DIV switches to increase the display height. Make sure both VOLTS/DIV controls are set to the same position, or the resultant display will be erroneous.

To set up the LBO-525L for differential operation, proceed as follows:

1. Set up for dual-trace operation per paragraph 2-3-5, Steps 1 to 6 and 8 to 10.
2. Ensure that both VOLTS/DIV switches (11) are set to the same position, and the VARIABLE controls (12) are detented in the CAL'D position. If the signal levels are very different, temporarily set both VOLTS/DIV switches to the position needed to produce a large on-screen display of the *highest-amplitude signal.*
3. Trigger from the channel having the highest amplitude signal.
4. Depress the CH-2 POL pushbutton (17).
5. Set the VERT MODE switch (16) to ADD. The single trace resulting in the algebraic difference of the CH-1 and CH-2 signals. Either or both of the Vertical POSITION controls (14) and (15) can be used to shift the resultant trace.

NOTE

If the input signals are in-phase, the amplitude of the resultant trace will be the arithmetic difference of the individual traces (e.g., 4.2 div − 1.2 div = 3.0 div). If the input signals are 180° out of phase, the amplitude of the resultant trace will be the arithmetic sum of the individual traces (e.g., 4.2 div + 1.2 div = 5.4 div).

6. If the peak-to-peak amplitude of the resultant trace is very low, turn *both* VOLTS/DIV switches to increase the waveform display height. Ensure that both VOLTS/DIV controls are set to the same position.

2-3-7 Delayed-timebase Operation

The LBO-525L features two timebases, arranged so one (the A timebase) may provide a delay between a trigger event and the beginning of sweep by the second (B) timebase. This allows any selected portion of a waveform, or one pulse of a pulse train, to be spread over the entire screen. Delayed sweep can be used with either single trace or dual trace operation. The procedure is the same regardless of the number of traces delayed.

Basic Delayed Sweep. For delayed sweep, proceed as follows:

1. Set up the LBO-525L as directed for whatever vertical mode you desire.
2. Ensure that the START pushbutton (27) is out.
3. Press the INTEN BY B pushbutton (26). A section of the trace(s) will intensify (brighten).

NOTE

The intensified portion will be quite small if there is a large difference between the settings of the A and B TIME/DIV switches.

4. Turn the B TIME/DIV control (21) until the intensified portion of the trace widens to an amount equal to the portion of the trace you wish to magnify (see Figure 2-12B).

5. Turn the DELAY TIME control (23) to position the intensification over the portion of the trace you wish to magnify (see Figure 2-12B).
6. Press the B HORIZ DISPLAY pushbutton (26). That portion of the trace intensified in Step 5 now appears spread over the full width of the CRT screen. The trace now displayed is being displayed on the B timebase (Figure 2-12C).
7. If need, additional enlargement is possible by pulling the TIME VARIABLE control (22) knob.

Triggered B Sweep. In basic delay sweep, the B timebase is *not* triggered by a signal event, it begins when the main sweep (A timebase) ends. An inherent characteristic of this is that main timebase jitter becomes noticeable in the B sweep when at high ratios of A to B TIME/DIV switch settings (100:1 and up). To reduce this, the B sweep can be triggered by the signal itself or a time-related trigger signal. The DELAY TIME control (23) then determines the *minimum* delay time between A and B sweeps; the actual delay time will be that plus the additional time until the next available trigger. The result is that actual delay time is variable only with step resolution, in increments of the interval between triggers.

For triggered B sweep proceed as follows:

1. Set up the scope for basic delayed sweep as described in the preceeding paragraphs.
2. Depress the START pushbutton (27). The B timebase is now triggering on the same trigger signal as the A timebase. The start of the B sweep will always be a leading or trailing edge of the trigger signal; turning the DELAY TIME control will not change this.

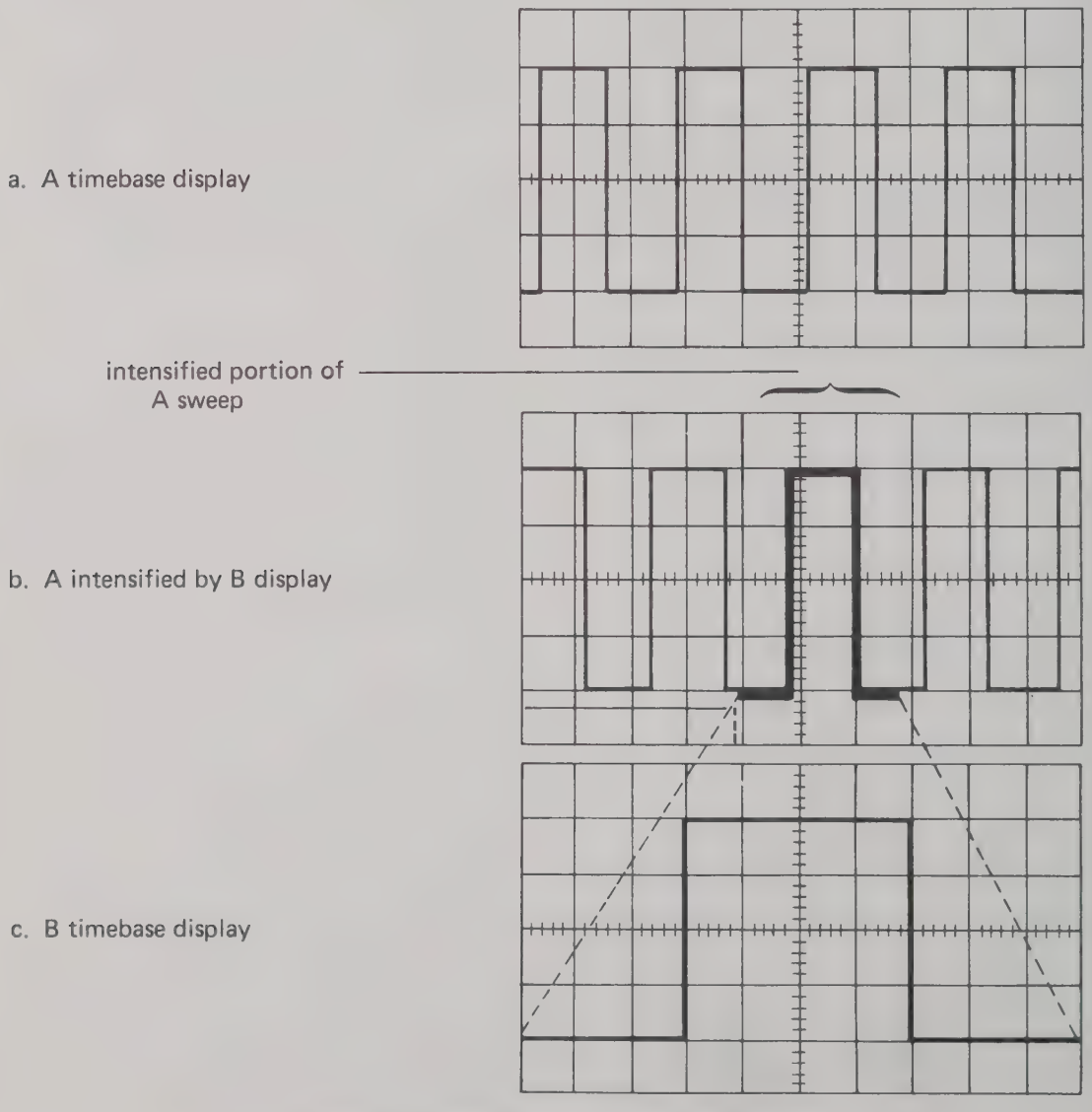


Figure 2-12. Sweep magnification by the B timebase

2-3-8 X–Y Operation

The internal timebases of the LBO-525L are not utilized in X-Y operation; deflection in both the vertical *and* horizontal directions is via external signals. One of the vertical input channels serves as the X-axis (horizontal) signal processor, so horizontal and vertical axes have identical control facilities.

All of the VERT MODE (16), HORIZ DISPLAY (26), trigger SOURCE (28), trigger COUPLING (24), and trigger mode switches, as well as their associated controls and connectors, are inoperative in the X-Y mode.

To set up the LBO-525L for X-Y operation, proceed as follows:

1. Turn the A TIME/DIV switch (20) fully counter-clockwise to the X-Y position.

CAUTION

Reduce the trace intensity, to reduce the risk of undeflected spot damage to the CRT phosphor.

2. Apply the vertical signal to the CH-2 or Y IN connector (10), and the horizontal signal to the CH-1 or X IN connector (9). Once the spot is deflected, restore normal brightness.
3. Adjust the trace height with the CH-2 VOLTS/DIV switch (11), and the trace width with the CH-1 VOLTS/DIV switch. The VARIABLE controls (12) and PULL X10 5 MHz switches (11) for both channels can be used if needed.

NOTE

Further horizontal (X- axis) magnification is available from the PULL X10 MAG switch (22), but is unlikely to be needed.

4. Adjust the trace position vertically (Y axis) with the CH-2 Vertical or Y POSITION control (15). Adjust the trace position horizontally (X axis) with the X FINE (25) and Horizontal POSITION controls (24); the CH-1 Vertical POSITION control has only slight effect during X-Y operation.
5. The vertical (Y-axis) signal can be inverted via the CH-2 POL pushbutton (17).

2-3-9 Intensity Modulation

Intensity modulation, also known as Z-axis modulation, is an operational mode wherein, an external signal controls the brightness of the CRT trace. Its main applications are are in video display and time or frequency marking. When so used, it is often in conjunction with X-Y operation (described in paragraph 2-3-8).

To intensity modulate the CRT, simply connect the modulating signal to the Z AXIS INPUT connector (34) on the back panel. The necessary modulating signal amplitude for minimum/maximum trace brightness is dependent upon the front panel intensity control. At normal brightness levels, a TTL signal (0 to 5 volts) will be sufficient.

CAUTION

Do not apply a signal greater than 50V (DC + AC peak).

2-4 MEASUREMENT APPLICATIONS

This contains instructions for using the LBO-525L for specific measurement procedures. However, this is but a small sampling of the many applications possible for this oscilloscope. These particular applications were selected to demonstrate certain controls and features not fully covered in BASIC OPERATING PROCEDURES, to clarify certain operations by example, or for their importance and universality.

2-4-1 Amplitude Measurement

The moder triggered-sweep oscilloscope has two major measurement functions. The first of these is amplitude. The oscilloscope has an advantage over most other forms of amplitude measurement in that complex as well as simple waveforms can be totally characterized (i.e., complete voltage information is available).

Oscilloscope voltage measurements generally fall into one of two types: peak-to-peak or instantaneous. Peak-to-peak (p-p) measurement simply notes the total amplitude between extremes without regard to polarity reference. Instantaneous voltage measurement indicates the exact voltage measurement indicates the exact voltage from each and every point on the waveform to a ground reference. When making either type of measurement, ensure that the VARIABLE controls (12) are detented fully clockwise in the CAL'D position.

Peak-to-Peak Voltages. To measure peak-to-peak voltage, proceed as follows.

1. Set up the LBO-525L for vertical mode desired per the instructions in 2-3 BASIC OPERATING PROCEDURES.
2. Adjust the TIME/DIV switch (20) or (21) to display two or three cycles of waveform, and set the VOLTS/DIV switch (11) for the largest-possible totally-on-screen display.
3. Use the appropriate Vertical POSITION control (14) or (15) to position the negative signal peaks on the nearest horizontal graticule line *below* the signal peaks, per Figure 2-13.
4. Use the Horizontal POSITION control (24) to position one of the positive peaks on the central vertical graticule line. This line has additional calibration marks equal to 0.2 major division each.
5. Count the number of divisions from the graticule line touching the negative signal peaks to the intersection of the positive signal with the central vertical graticule line. Multiply this number by the VOLTS/DIV switch setting to obtain the peak-to-peak voltage of the waveform. For example, if the VOLTS/DIV switch were set to 2V, the waveform shown in Figure 2-13 would be 11.2V p-p (5.6 div x 2V).

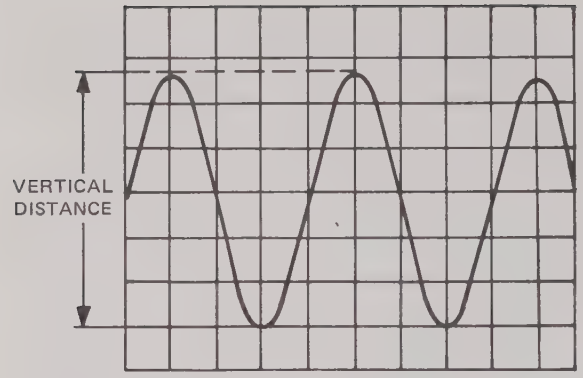


Figure 2-13. Peak-to-peak voltage measurement

6. If X10 vertical magnification is used, divide the Step 5 voltage by 10 to obtain the correct p-p voltage. However if 10X attenuator probes are used, multply the VOLTS/DIV by 10 to obtain the correct p-p voltage.
7. If measuring a sine wave below 100 Hz, or a rectangular wave below 1000 Hz, set the AC/GND/DC switch (13) to DC.

CAUTION

Ensure that the waveform is not imposed on a higher-amplitude DC voltage.

Instantaneous Voltages. To measure instantaneous voltage, proceed as follows.

1. Set up the LBO-525L for the vertical mode desired per the instructions in 2-3 BASIC OPERATING PROCEDURES.
2. Adjust the applicable TIME/DIV switch (20) or (21) for one complete cycle of waveform and set the VOLTS/DIV switch (11) for a trace amplitude of 4 to 6 divisions (see Figure 2-14).

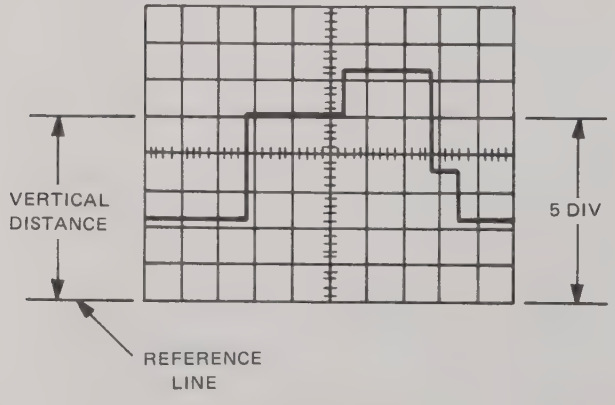


Figure 2-14. Instantaneous voltage measurement

3. Set the AC/GND/DC switch (13) to GND.
4. Use the appropriate Vertical POSITION control (14) or (15) to set the baseline on the central horizontal graticule line. However, if you know the signal voltage is wholly positive, use the bottommost graticule line. If you know the signal voltage to be negative, use the uppermost graticule line.

NOTE

The Vertical POSITION controls must not be touched again until the measurement is completed.

5. Set the AC/GND/DC switch to DC. The polarity of all points above the ground-reference line is positive; all points below the ground-reference line are negative.

CAUTION

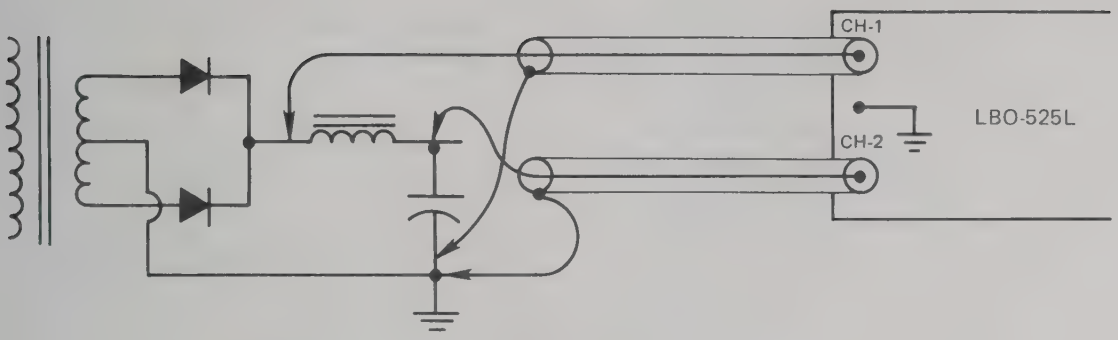
Ensure that the waveform is not imposed on a high-amplitude DC voltage before changing the AC/GND/DC switch setting.

6. Use the Horizontal POSITION control (24) to position any point of interest on the central vertical graticule line. This line has additional calibration marks equal to 0.2 major division each. The voltage relative to ground at any point selected is equal to the number of divisions from that point to the ground-reference line multiplied by the VOLTS/DIV setting. In the example used for Figure 2-14, the voltage for a 0.5V/div scale is 2.5V (5.0 div x .5V).
7. If 10X vertical magnification is used, divide the Step 6 voltage by 10. However, if 10X attenuator probes are used, multiply the voltage by 10.

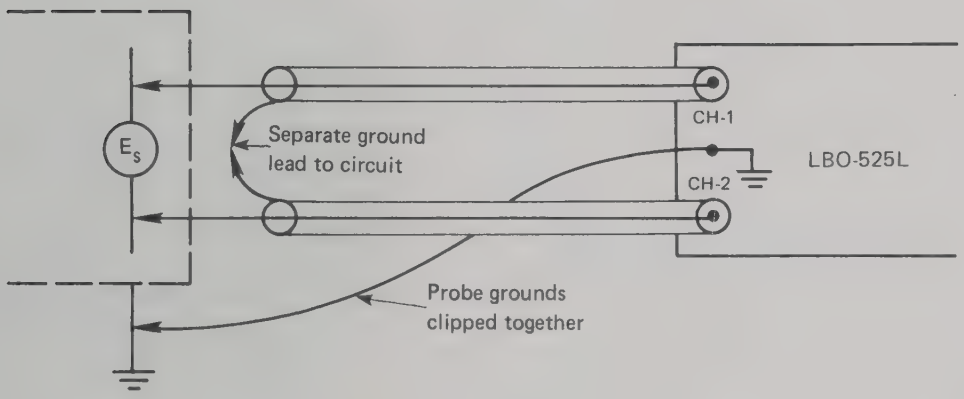
2-4-2 Differential Measurement Techniques

Differential measurement techniques allow direct measurement of the voltage drop across "floating" components (both ends above ground), and measurement of very-small signals in electrically-noisy environments (such as exists near high-power AC machinery.

The control settings for differential operation were explained in paragraph *2-3-6 Additive and Differential Operation.* The technique for making the physical connections are shown in Figure 2-15. Figure 2-15A shows the simple technique for measuring high-level signals on floating signals. In this example, the AC voltage drop (ripple) across a power choke is observed and measured. The ground terminals from the two probes or cables are simply connected to the chassis or ground bus of the circuit under observation. Figure 2-15B shows the connection technique needed for low-level signals in a noisy environment (strong AC fields). Using a separate ground connection and *not* connecting the probe shields to the circuit under test avoids ground loops and EMI pickup.



a. High-level signal connections



b. Low-level technique

Figure 2-15. Connection technique for differential measurements

2-4-3 Time Interval Measurements

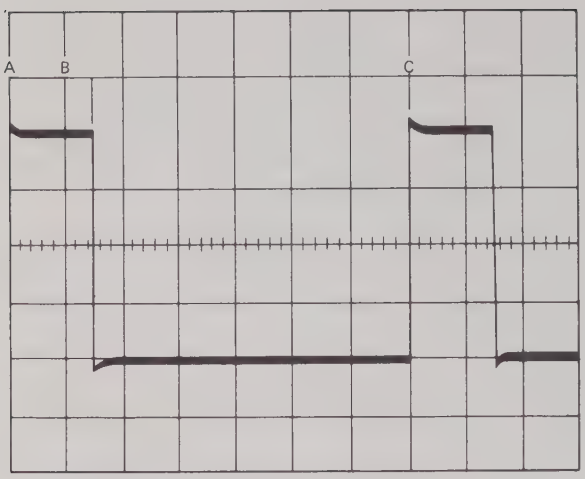
The second major measurement function of the triggered-sweep oscilloscope is the measurement of time interval. This is possible because the calibrated timebase results in each division of the CRT screen representing a known time interval.

Basic Technique. The basic technique for measuring time interval is described in the following steps. This same technique applies to the more specific procedures and variations that follow.

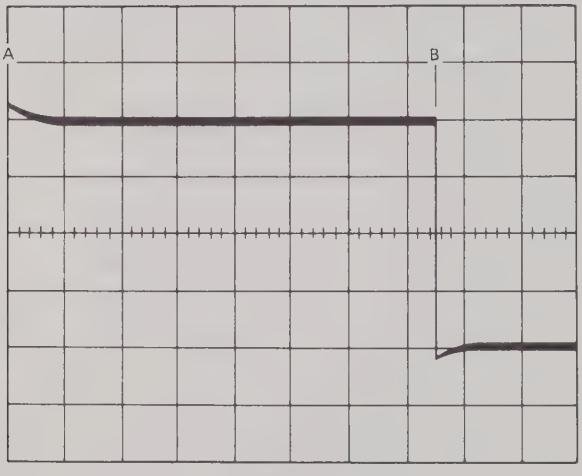
1. Set up the LBO-525L as described in *2-3-2 Single trace Operation.*
2. Set the A TIME/DIV switch (20) so the interval you wish to measure is totally on screen and as large as possible. Ensure that the TIME VARIABLE control (22) is detented fully clockwise in the CAL'D position. If not, any time interval measurements made under this condition will be inaccurate.
3. Use the Vertical POSITION control (14) or (15) to position the trace so the central horizontal graticule line passes through the points on the waveform between which you want to make the measurement.
4. Use the Horizontal POSITION (24) and X FINE control (25) to set the left-most measurement point on a nearby vertical graticule line.
5. Count the number of horizontal graticule divisions between the Step 4 graticule line and the second measurement point. Measure to a tenth of a major division. Note that each minor division on the central horizontal graticule line is 0.2 major division.
6. To determine the time interval between the two measurement points, multiply the number of horizontal divisions counted in Step 5 by the setting of the A TIME/DIV switch. If the TIME VARIABLE knob (22) is pulled (X10 magnification), be certain to divide the TIME/DIV switch setting by 10.

Period, Pulse Width, and Duty Cycle. The basic technique described in the preceeding paragraph can be used to determine pulse parameters such as period, pulse width, duty cycle, etc.

The period of a pulse or any other waveform is the time it takes for one full cycle of the signal. In Figure 2-16, the distance between points (A) and (C) represent one cycle; the time interval of this distance is the period. The time



a. 10MS/DIVISION



b. 2 MS/DIVISION

Figure 2-16. Time interval measurement

scale for the CRT display of Figure 2-16A is 10 mS/div, so the period is 70 milliseconds in this example.

Pulse width is the distance between points (A) and (B). In our example it is conveniently 1.5 divisions, so the pulse width is 15 milliseconds. However, 1.5 divisions is a rather small distance for accurate measuremnets, so it is adviseable to use a faster sweep for this particular measurement. Increasing the sweep speed to 2 mS/div as in Figure 2-16B presents a large display, allowing more accurate measurement. An alternative technique useful for pulses less than a division wide is to pull the TIME VARIABLE knob (22) for X10 magnification, and reposition the pulse on screen with the Horizontal POSITION control (24). Pulse width is also called *on* time in some applications. The distance between points (B) and (C) is then called *off* time. This can be measured in the same manner as pulse width.

When pulse width and period time are known, duty cycle can be calculated. Duty cycle is the percentage of the period (or total of *on* and *off* times) represented by the pulse width (*on* time).

$$\text{Duty cycle (\%)} = \frac{\text{PW (100)}}{\text{Period}} = \frac{\text{A} \rightarrow \text{B (100)}}{\text{A} \rightarrow \text{C}}$$

$$\text{Duty cycle of example} = \frac{15 \text{ mS X100}}{70 \text{ mS}} = 21.4\%$$

Lead and Lag Time.

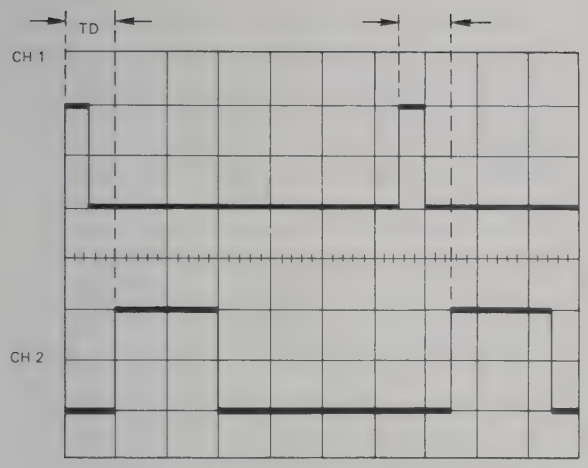
When two signals have the same frequency, but not the same phase, one signal is said to be *leading* and the other *lagging*. To measure this lead/lag time, proceed as follows.

1. Set up the LBO-525L as described in *2-3-5 Dual-trace Operation*, connecting one signal to the CH-1 Input connector (9) and the other to the CH-2 Input connector (10).

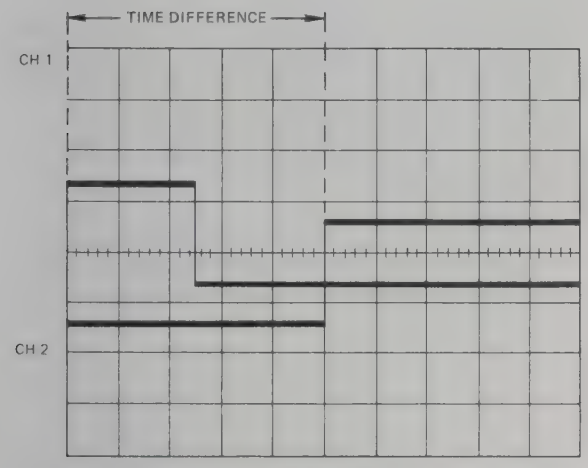
NOTE

At high frequencies use identical and correctly-compensated probes, or equal lengths of the same type of coaxial cable to ensure equal delay times.

2. Set the trigger SOURCE switch (28) for the channel with the leading signal (CH-1 in the Figure 2-17 example).
3. Use the A TIME/DIV switch (20) to display the time difference as large as possible (Figure 2-17B).
4. Use the CH-1 Vertical POSITION control (14) to position the bottom of the channel 1 trace slightly below the central horizontal graticule line, and the CH-2 Vertical POSITION control (15) to position the top of the channel 2 trace slightly above the line.
5. Use the Horizontal POSITION control (24) and X FINE (25) control to align the left-most trace edge (of channel 1 in this case) with a nearby vertical graticule line. The horizontal distance between this line and the point at which the leading edge of the other trace crosses the central horizontal graticule line represents the time difference between the two signals. The channel 1 signal may be said to be leading the channel 2 trace, or the channel 2 trace may be said to be lagging the channel 1 trace.
6. Ensure that the TIME VARIABLE control (20) is detented fully clockwise in its CAL'D position. Then, count the number of horizontal divisions between the leading edges of the traces and multiply this number by the setting of the A TIME/DIV switch to determine the difference. For example, the time difference in Figure 2-17B is 10 microseconds (5.0 div x 2 μS).



a. 10 MS/DIVISION



b. 2 μS/DIVISION

Figure 2-17. Measuring lead and lag time

If the points between which the time difference exists are less than 1 major division apart and located in the middle of complex waveforms that are otherwise in phase, use the delayed (B) timebase as described in *2-3-7 Delayed Timebase Operation* to select and expand that section of the complex waveform. After doing that, follow the same technique as described in the preceeding paragraph. As an alternative, pull the TIME VARIABLE knob (22) to expand the traces, and reposition the section with the time difference on screen with the Horizontal POSITION and X FINE (25) controls.

If the points bewteen which the time difference exists are more than 1 but less than 5 major divisions apart, the High-Accuracy Technique described next will yield the greatest accuracy.

High-accuracy Techniques. Closely-spaced points within a complex waveform can be measured using the DELAY TIME control. The linearity error of this control is only a fraction of a percent, far less than the error possible over a small portion of this timebase sweep.

The delay-time technique can be used with single-trace time measurements (pulse width, period, etc.) or dual-trace measurements (lead and lag time). The technique, after the trace or traces are set up according to the desired procedure, is as follows:

1. Set the B TIME/DIV switch (21) to a position 50 to 100 times (5 to 6 positions) faster than the A TIME/DIV switch setting.
2. Press the INTEN BY HORIZ DISPLAY pushbutton (26), then position the intensified area over the first measurement point by means of the DELAY TIME control (23).
3. Press the B HORIZ DISPLAY pushbutton (26) and carefully adjust the DELAY TIME control to position the first measurement point exactly over the central vertical graticule line. Record the DELAY TIME dial reading.
4. Turn the DELAY TIME control to position the second measurement point over the central vertical graticule line. Record the DELAY TIME dial reading.
5. Subtract the Step 3 reading from the Step 4 reading. For example, if the DELAY TIME control setting was 4.86 in Step 3, and 7.38 in Step 4, the difference is 2.51.
6. Multiply the Step 5 number by the A TIME/DIV switch setting to find difference.

2-4-4 Phase Difference Measurements

Phase difference or phase angle between two signals can be measured using the dual trace feature of the oscilloscope or by operating the oscilloscope in the X–Y mode. When measuring phase shift or signal-processing devices, the test setup shown in Figure 2-21 can be used.

Dual-trace Method. This method works with any type of waveform (sine, triangle, rectangular, complex pulse, etc.). In fact, it will usually work even if different waveforms are being compared. This methods and its variations are effective in measuring small or large differences in phase, at any frequency up to 50 MHz.

To measure phase difference by the dual-trace method, proceed as follows:

1. Set up the LBO-525L as described in *2-3-5 Dual-trace Operation*, connecting one signal to the CH-1 or X IN connector (9) and the other to the CH-2 or Y IN connector (10).

NOTE

At high frequencies use identical and correctly-compensated probes, or equal lengths of the same type of coaxial cable to ensure equal delay times, or erroneous time measurements will result.

2. Set the trigger SOURCE switch (28) to the channel with the least noise and most stable trace. Temporarily move the other channel's trace off the screen by means of its Vertical POSITION control.
3. Center the stable (trigger source) trace with its Vertical POSITION control, and adjust its amplitude to exactly 6 vertical division by means of its VOLTS/DIV switch (11) and VARIABLE control (12).
4. Use the LEVEL control (31) to ensure the trace crosses the central horizontal line at or near the beginning of the sweep. (See Figure 2-18.)
5. Use the A TIME/DIV switch (20), the TIME VARIABLE control (22), and the Horizontal POSITION control (24) to display one cycle of trace over 7.2 divisions. When this is done, each major horizontal division represents 50°, and each minor division represents 10°.
6. Move the off-screen trace back on the CRT with its Vertical POSITION control, precisely centering it vertically. Use the associated VOLTS/DIV switch and VARIABLE control to adjust its amplitude to exactly 6 vertical divisions.
7. The horizontal distance between corresponding points on the waveform is the phase difference. For example, in the Figure 2-18 illustration the phase difference is 6 minor divisions, or 60°, Use the X FINE control (25) to align one of the mid-cycle zero crossings with a graticule calibration to facilitate this measurement.
8. If the phase difference is less than 50° (one major division), pull the TIME VARIABLE knob (22), and use the Horizontal POSITION control (24) (if needed) to position the measurement area back on screen. With 10X magnification, each major horizontal division is 5°, and each minor division is 1°.

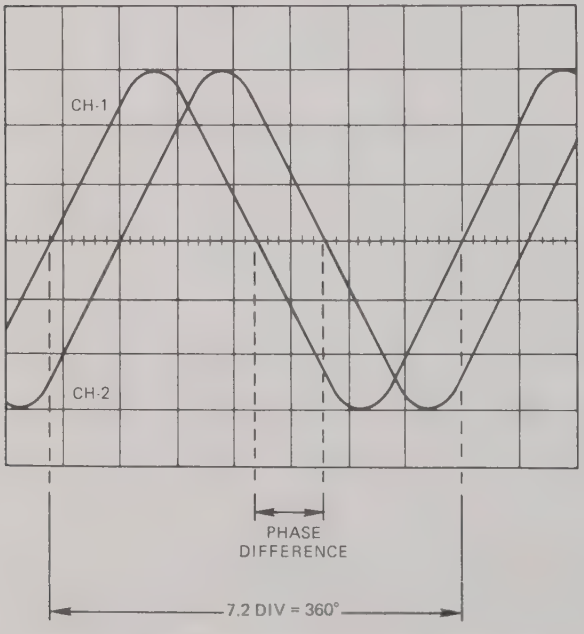


Figure 2-18. Dual-trace method of phase measurement

Lissajous Pattern Method. This method is used primarily with sine waves. Measurements are possible at frequencies up to 1 MHz, the bandwidth of the horizontal amplifier.

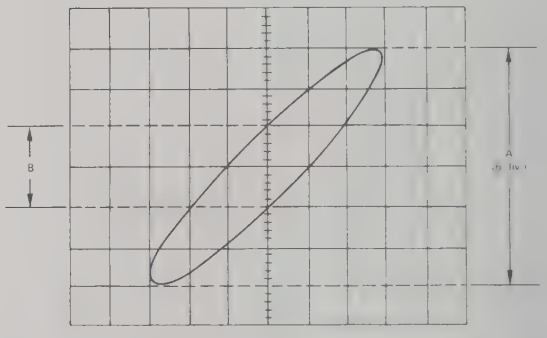
To measure phase difference by the Lissajous pattern method, proceed as follows:

1. Turn the A TIME/DIV switch (20) fully counterclockwise to the X-Y position.

CAUTION

Reduce the trace intensity, to reduce the risk of undeflected spot damage to the CRT phosphor.

2. Make certain the CH-2 POL switch (17) is out. This will introduce a 180° error if pushed in.
3. Connect one signal to the CH-1 or X IN connector (9), and the other signal to the CH-2 or Y IN connector (10).
4. Center the trace vertically with the CH-2 Vertical POSITION control (15), and adjust the CH-2 VOLTS/DIV switch (11) and VARIABLE control (12) for a trace height of exactly 6 divisions (the 100% and 0% graticule lines tangent to the trace).
5. Adjust the CH-1 VOLTS/DIV control (11) for the largest possible on-screen display.
6. *Precisely* center the trace horizontally with the Horizontal POSITION (24) or X FINE (25).
7. Count the number of divisions subtended by the trace along the central vertical graticule line (dimension B). You can now shift the trace vertically with the CH-2 or Y POSITION control to a major division line for easier counting.



$\theta = \text{arc sine } \frac{B}{A}$ $\theta = \text{arc sine } \frac{\text{Step 7 divs}}{6}$

a. Phase angle calculation

b. Lissajous patterns of various phase angles

Figure 2-19. Lissajous Method of Phase Measurement

8. The phase difference (angle 0) between the two signals is equal to the arc sine of dimension B ÷ A (the Step 7 number divided by 6). For example, the Step 7 value of the Figure 2-19A pattern is 2.0. Dividing this by 6 yields .3334, whose arc sine is 19.5 degrees.
9. The simple formula in Figure 2-19A works for angles less than 90°. For angles over 90° (leftward tilt), add 90° to the angle found in Step 7. Figure 2-19B shows the Lissajous patterns of various phase angles; use this as a guide in determining whether or not to add the additional 90°.
10. The sine-to-angle conversion can be accomplished by using trig tables or a trig calculator. However, if the sine is between 0.1 and 1.0, you can use the Figure 2-20 monograph so the edge passes through the cross mark and the number of divisions measured in Step 7 (B dimension). When this is done the edge will also intersect the phase-angle column.

2-4-5 Distortion Comparison

The dual-trace feature of the LBO-525L offers a quick method of checking for distortion caused by a signal-processing device (such as an amplifier). To do this, proceed as follows:

1. Connect the output of a signal generator (of frequency suitable to the device under test) to the CH-1 or X IN connector (9) and the input of the Device Under Test (DUT).
2. Connect the CH-2 or Y IN connector (10) to the output of the device or its load (see Figure 2-21).
3. Increase the signal to the DUT until the channel 2 trace or an RMS AC voltmeter indicates the desired output level.
4. If the DUT has reversed, the phase, press the CH-2 POL pushbutton (17).
5. Superimpose the two traces with the Vertical POSITION controls (14) and (15), and use the VARIABLE control (12) of the *highest* amplitude trace to achieve the best trace match.
6. Any *uniform horizontal* displacement of the trace is simply phase difference (described in paragraph 2-4-4). Any other differences in shape indicate distortion caused by the DUT, such as slew rate or frequency distortion, ringing, etc.

2-4-6 Frequency Measurements

When a precise determination of frequency is needed, a frequency counter is obviously the first choice. However, an oscilloscope can be used in either of two ways to measure frequency when a counter is not available, or modulation and/or noise makes the counter unusable.

Reciprocal Method. Frequency is the reciprocal of period. Simply measure the period "t" of the unknown signal as instructed in *2-4-3 Time Interval Measurements*, and calculate the frequency "f" using the formula f = 1/t. If a calculator is available, simply enter the period and press the 1/x key. Period in seconds (S) yields frequency in hertz (Hz); period in milliseconds (mS) yields frequency in kilohertz (kHz); period in microseconds (μS) yields frequency in megahertz (MHz). The accuracy of this technique is limited by the timebase accuracy (see Table of Specifications).

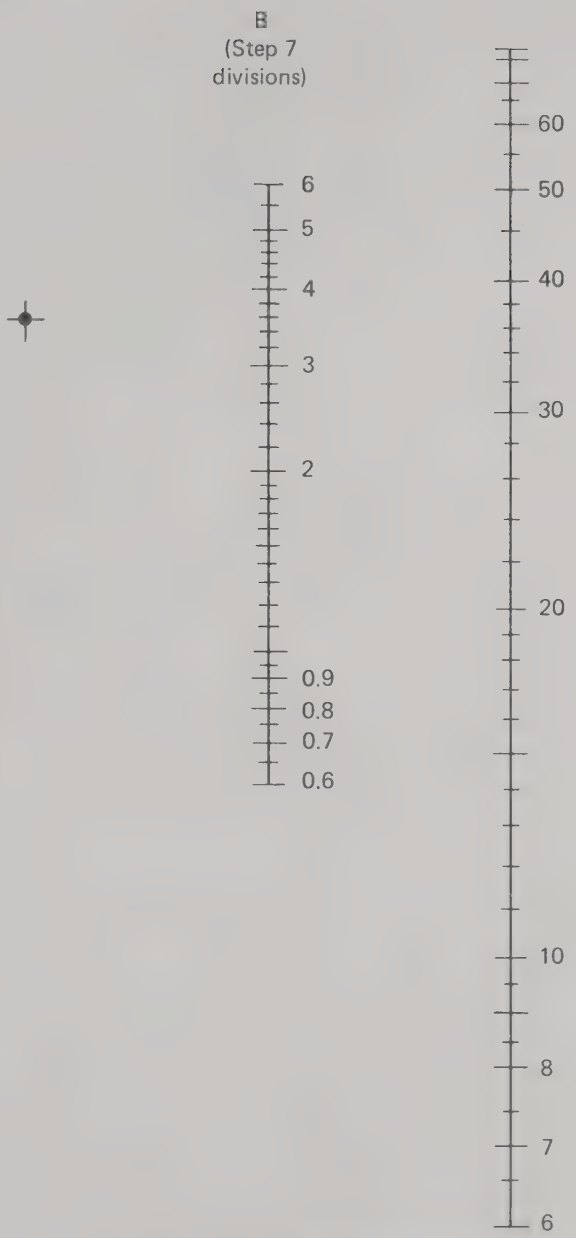


Figure 2-20. Phase angle nomograph

Comparison Method. In the frequency-comparison or frequency-ratio method, the unknown frequency is compared to a known frequency (from a calibrated signal generator). The two signals are fed to the oscilloscope operating in its X-Y mode, and the signal generator frequency is varied until a recognizable Lissajous pattern

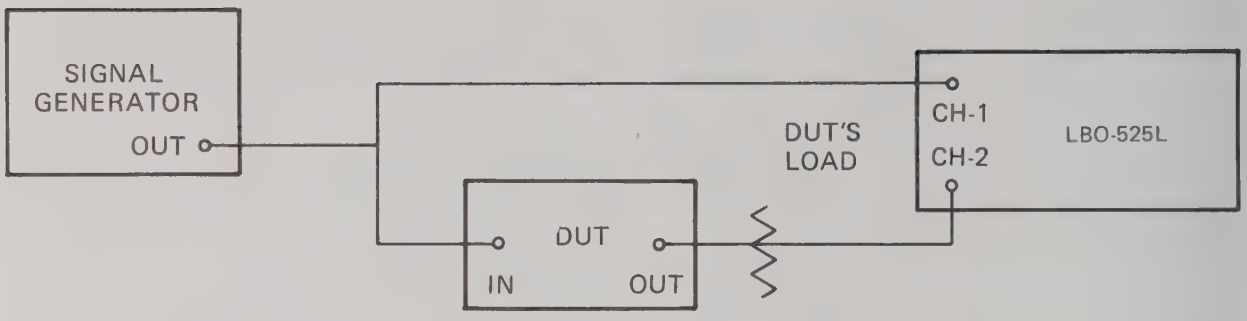


Figure 2-21. Test setup for distortion comparison and phase measurement

appears. The pattern shape indicates the ratio between the two frequencies. When the generator frequency is multiplied by this ratio, the unknown frequency will be determined. This method is usable for frequencies up to 1 MHz.

To measure frequency by the comparison method,. proceed as follows:

1. Set up the LBO-525L for X-Y operation (paragraph 2-3-8).
2. Connect the output of a signal generator having accurate frequency calibration to the CH-1 or X IN connector (9).
3. Adjust the CH-1 VOLTS/DIV switch (11) for a display of approximately 6 divisions of horizontal deflection.
4. Connect the signal with the unknown frequency to the CH-2 or Y IN connector (10).
5. Adjust the CH-2 VOLTS/DIV switch (11) for a display of approximately 6 divisions of vertical deflection.
6. Vary the frequency of the signal generator until the scope display resembles a circle, an ellipse, or a diagonal line. When this occurs the unknown frequency is the same as the signal generator frequency (which can be read from its dial). The accuracy of this technique depends on the signal generator's calibration accuracy.

NOTE

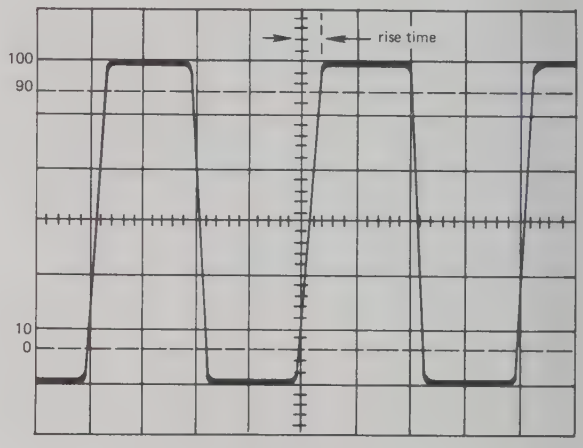
While many other ratios are theoretically possible, drift in either signal frequency makes more complex Lissajous patterns nearly impossible to read.

2-4-7 Risetime Measurement

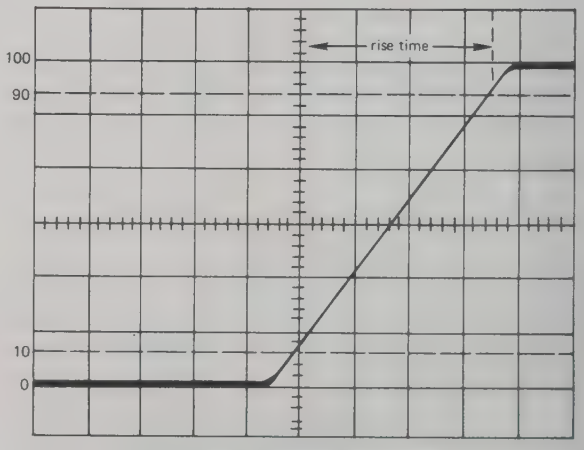
Risetime is the time required for the leading edge of a pulse to rise from 10% to 90% of the total pulse amplitude. Falltime is the time required for the trailing edge of a pulse to drop from 90% of total pulse amplitude to 10%. Risetime and falltime, which may be collectively called transition time, are measured in essentially the same manner.

To measure rise and fall time, proceed as follows:

1. Connect the pulse to be measured to the CH-1 or X IN connector (9), and set the AC/GND/DC switch (13) to AC.



a. Basic display setup



b. With 10X horizontal magnification

Figure 2-22. Risetime measurement

2. Adjust the A TIME/DIV switch (20) to display *about* 2 cycles of the pulse. Make certain the TIME VARIABLE control (22) is detented fully clockwise in the CAL'D position.
3. Center the pulse vertically with the channel 1 Vertical POSITION control (14).
4. Adjust the CH-1 VOLTS/DIV switch (11) to set the postive pulse peak exceed the 100% graticule line, and the negative pulse peak exceed the 0% line, then rotate the VARIABLE control (12) counterclockwise until the positive and negative pulse peaks rest exactly on the 100% and 0% graticule lines. (See Figure 2-22A.)
5. Use the Horizontal POSITION (24) and X FINE (25) controls to shift the trace so the leading edge passes through the intersection of the 10% and central vertical graticule lines.
6. If the risetime is slow compared to the period, no further control manipulations are necessary. If the risetime is fast (leading edge almost vertical), pull the TIME VARIABLE knob (22) for 10X magnification and reposition the trace as in Step 5. (See Figure 2-22B).
7. Count the number of horizontal divisions between the central vertical line (10% point) and the intersection of the trace with the 90% line.
8. Multiply the number of divisions counted in Step 7 by the setting of the A TIME/DIV switch to find the measured risetime. If 10X magnification was used, divide the TIME/DIV setting by 10. For example, if the A timebase setting in Figure 2-22B was .2 μS (200 nS), the risetime would be 72 nanoseconds (200 nS ÷ 10 = 20 nS; 20 nS x 3.6 div = 72 nS).
9. To measure falltime, simply shift the trace horizontally until a trailing edge passes through the 10% and central vertical graticule lines, and repeat Steps 7 and 8.
10. The rise and fall times measured thus far include the 10 nS transition times of the LBO-525L (7 nS with probe). These errors are negligible if the measured rise and fall times are 40 nS or longer. For shorter transition times, correct the measured rise and fall times using the following formula.

$$t_c = \sqrt{t_m^2 - 49}$$

t_c = corrected transition t_m = measured transition time

Continuing with example, the 72 nS risetime measured in Step 8 represents an actual risetime of 71.66 nS for the pulse when corrected for scope and probe risetime as follows:

$$t_c = \sqrt{72^2 - 49} = \sqrt{5135} = 71.66 \text{ nS}$$

3. ADJUSTMENT AND CALIBRATION PROCEDURES

3-1 POWER SUPPLY

3-1-1 Check and adjust voltages on corresponding test points shown in table 3-1

VOLTAGE	TEST POINT	ADJUSTMENT
+270	TP1	(on the PCB #T-2503)
+100	TP2	(on the PCB #T-2503)
−12	TP3	(on the PCB #T-2503)
+12	TP4	(on the PCB #T-2503)
+5	TP5	(on the PCB #T-2503)
−1900	TP6	(VC2 on the PCB #T-2503)

3-2 DISPLAY

3-2-1 SET: HORIZ DISPLAY A
TIME/DIV .5 ms
VERT MODE CH 1
TRIG Auto

Connect an oscilloscope to TP7 of PCB T-2503

Set the front panel INTEN control to minimum Intensity and check for leads shown in figure (3-1a).

Set the INTEN control to Maximum intensity and check for levels shown in figure (3-1a).

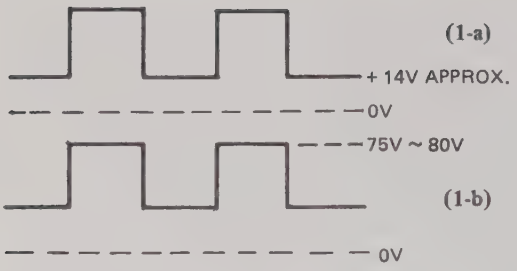


Figure 1

3-2-2 Intensity Adjustment

Position INTEN Control as shown in figure 3-2

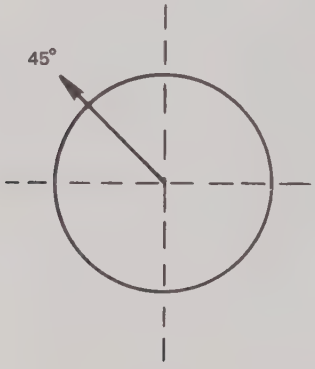


Figure 2

Adjust VR1 (PCB T-2503) so that trace just appears on CRT

3-2-3 Astigmatism and Focus

SET:	FOCUS	Fully C.C.W.
	TIME/DIV	X-Y

Connect a sine wave generator to the Y (CH-2) input of the oscilloscope and set the generator output to 1 kHz.

Adjust the generator output for 8 divisions of vertical deflection on the CRT

Adjust VR4 on PCB T-2503 and FOCUS control on front panel to obtain the sharpest and most uniform trace thickness

3-3 VERTICAL AMPLIFIER

3-3-1 DC Balance

SET:	HORIZ DISPLAY	A
	AC-GND-DC	GND
	VERT MODE	CH-1
	VOLTS/DIV VARIABLE	F.C.C.W.

Position the CH-1 trace to the center horizontal graticule line.

Rotate the Variable Knob to fully clockwise (CAL'D) position. Check that the trace shift is less than .5 major division between VARIABLE Knob and C.C.W. and C.W. positions. If the trace shift is more than .5 major division, adjust VR3 on PCB T-3003 using the following procedure:

Set the VOLTS/DIV VARIABLE to fully C.C.W.

Position the trace on the center horizontal graticule line using the vertical position control. Set the VOLTS/DIV VARIABLE to fully clockwise. Position the trace on the center horizontal graticule line using the CH-1 DC BALANCE ADJ (VR3 on PCB T-3003).

Repeat the above procedure for a minimum of trace shift when rotating the CH-1 variable knob as necessary.

CH-2—Repeat the same procedure for CH-2 by adjusting VR103 (PCB T-3003)

3-3-2 Vertical Position Centering

For CH-1 set the VERT POS control to midrange. Adjust trimpot VR6 (PCB T-3003) to center the trace on the CRT display.

For CH-2 set the VERT POS control to midrange. Adjust trimpot VR106 (PCB T-3003) to center the trace on the CRT display.

3-3-3 CH-2 Invert Balance

Position the trace on the center horizontal graticule line using the CH-2 vertical position control. Depress the VERT MODE CH-2 POL INV button. Adjust INV Balance VR105 (PCB T-3003) for minimum trace shift between CH-2 INV in and out.

3-3-4 AC Gain Adjustment

SET:	VOLTS/DIV	5 mV
	VARIABLE	CAL'D
	AC-GND-DC	DC

Connect a square wave generator the CH-1 input connector

Frequency—100 kHz
Output—4 division display

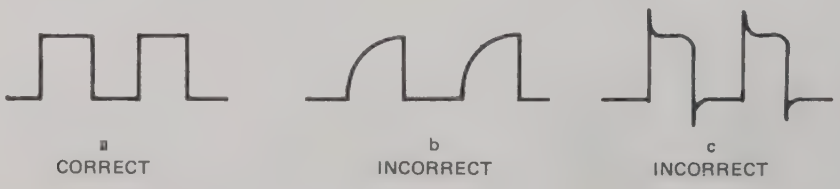


Figure 3

Adjust VR1 (PCB T-3003) for a flat top square wave CRT display see figure 3-3a.

For CH-2 Repeat above steps and adjust VR101 (PCB T-3003).

3-3-3 VOLTS/DIV (Vertical Amplifier Gain) Adjustment

SET: VOLTS/DIV 5 mV
VARIABLE CAL'D
AC-GND-DC DC

Connect an amplitude calibrator and adjust the freqguency for 100 kHz, adjust amplitude out for 20 mV p-p. Check display for vertical deflection between 3.88 and 4.12 major divisions. If adjustment is necessary, adjust VR8 (PCB T-3003) for a 4 division display on the CRT. Check and adjust all VOLTS/DIV ranges according to table 1.

CH-2: Repeat the same procedure for CH-2 by adjusting VR108 (PCB T-3003).

TABLE 1

VOLTS/DIV	CALIBRATOR OUTPUT	DEFLECTION
5 mV	20 mV	4 DIV ±3%
10 mV	50 mV	5 DIV ±3%
20 mV	0.1 V	5 DIV ±3%
50 mV	0.2 V	4 DIV ±3%
.1 V	0.5 V	5 DIV ±3%
.2 V	1 V	5 DIV ±3%
.5 V	2 V	4 DIV ±3%
1 V	5 V	5 DIV ±3%
2 V	10 V	5 DIV ±3%
5 V	20 V	4 DIV ±3%

3-3-6 X10 AC GAIN Adjustment

SET CH-1: Volts/DIV 20 mV
VARIABLE CAL'D, PULL (X10 MAG)
AC-GND-DC DC

Connect the amplitude calibrator and adjust the frequency for 100 kHz.

Adjust amplitude out for mV p-p. Adjust VR2 (PCB T-3003) for 5 major divisions of vertical deflection on the CRT.

CH-2: Repeat the same procedure for CH-2 by adjusting VR102 (PCB T-3003)

3-3-7 HF Response Adjustment

SET: VOLTS/DIV 5 mV
VARIABLE CAL'D
AC-GND-DC DC

Apply a 100 kHz fast rise square wave (5 nS risetime maximum) to the CH-1 input connector at an amplitude of approx. 25 mV p-p.

Adjust VC9, 10, 11 (PCB T-3003) and VC1, 2 (PCB T-3004) for the best possible flat top square wave display as in figure 3.4A.

CAUTION

This is recommended factory adjustment only.

SET: CH-1 VOLTS/DIV 5 mV
VARIABLE CAL'D
AC-GND-DC DC

Apply a 100 kHz squarewave generator to the CH-1 input connector and adjust amplitude for a 4 division display.

Adjust VC8 for an overshoot of 5% (.2 div) as shown in figure 3-4a .

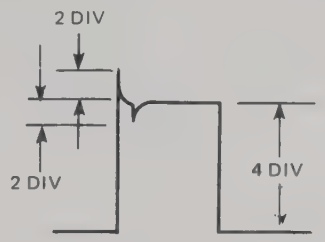


Figure 3-4a

Frequency overshoot will be within tolerance after the above adjustment is completed.

Check to ensure that overshoot is still within tolerance on 10 mV and 20 mV ranges.

CH-2: Repeat the same procedure for CH-2 by adjusting VR109, 110, 111, 112 (PCB T-3003).

3-3-8 Vertical Attenuator Phase Compensation

CAUTION

This is recommended for factory alignment only

SET: CH-1 VOLTS/DIV 50 mV
VARIABLE CAL'D (Depressed)
AC-GND-DC DC

Apply a 100 kHz aquare wave at an amplitude of .25V p-p to the CH-1 input connector. Adjust VC1 (T-2554) for the best possible flat top square wave display.

Adjust other phase compensation trimmers as indicated on table 2.

CH-2: Repeat above procedure using the same table where indicated for CH-2.

TABLE 2

	Volts/ Div	Phase Compensation Trimmer	Squarewave Generator Amplitude
CH-1	50 mV	VC6 (T-3003)	0.25 V p-p
	100 mV	VC8 (T-3003)	0.5 V p-p
	200 mV	VC2 (T-3003)	1 V p-p
	2 V	VC4 (T-3003)	10 V p-p
CH-2	50 mV	VC106 (T-3003)	0.25 V p-p
	100 mV	VC108 (T-3003)	0.5 V p-p
	200 mV	VC102 (T-3003)	1 V pp
	2 V	VC104 (T-3003)	10 V p-p

3-3-9 Input Capacitance Adjustment

SET: CH-1 VOLTS/DIV 5 mV

1. Connect a capacitance meter to the CH-1 Input connector.
   Measure the capacitance and record this value.
   Set the VOLTS/DIV switch to 50 mV, and adjust VC5 (T-3003) so that it reads approximately the same as the recorded value in step 1.
2. Adjust other capacitor adjustments to the same value using table 3
3. CH-2: Repeat above steps for CH-2 using same table where indicated for CH-2.
4. Upon completion of capacitance adjustments, the difference in value between CH-1 and CH-2 must be within .5 pF. If not, readjust as necessary.

TABLE 3

	INPUT CAPACITANCE ADJUSTMENT
CH-1	VC1 VC3 VC5 VC7
CH-2	VC101 VC103 VC105 VC104

3-4 TIME BASE

3-4-1 A SWEEP TIME ADJUSTMENT

SET: A TIME/DIV .5 mS
VARIABLE CAL'D

Connect a time marker generator to the CH-1 Input connector and set it for a .5 mS output.

Adjust WIDTH VR6 (T-2502 so that both the start and stop of the trace are displayed on the CRT.

Adjust A TIME VARIABLE VR2 (T-2502) until 8 pulses are displayed on the CRT from end to end.

Adjust VR6 (T-2502) to place a marker on each vertical graticule line (1 DIV).

Check the length of the trace for 12 divisions
(Note: Only 8 divisions can be displayed at one time so the HORIZ POS control will have to be rotated until 4 extra divisions are visible after the first 8 have been removed from the CRT display.

Set the A TIME/DIV to 5 mS and set the output of the time marker generator for a 5 mS output.

Adjust VR6 (T-2502) to place a marker on each vertical graticual line.

Set the A TIME/DIV to 5 μS and set the output of the time marker generator for 5 μS.

Adjust VC1 (T-2502) to place a marker on each graticule line.

3-4-2 B Sweep Time Adjustment

SET: HORIZON DISPLAY B
8 TIME/DIV 5 μS

Connect a time marker generator to the CH-1 input connector and set it for a 5 μS output.

Adjust VR4 (T-2502) to place a marker on each vertical graticule line.

3-4-3 Start and End Adjustment of Delay Time

SET: A TIME/DIV .1 mS
B TIME/DIV 5 μS
HORIZ DISPLAY A INTEN BY B

Using the HORIZ POS control. Set the start point of the A Sweep to 0.15 major division to the left of the far left vertical line on the scale. With the DELAY TIME control set to 0.0 adjust VR3 (T-2507) until the leading edge of the intensified sweep occurs at the far left vertical graticule line on the scale (see fig. 3-4b).

Set the DELAY TIME control to 10.0. Adjust VR1 (T-2507) until the leading edge of the intensified sweep occurs at the far right vertical graticule line on the scale (see fig. 3-4b).

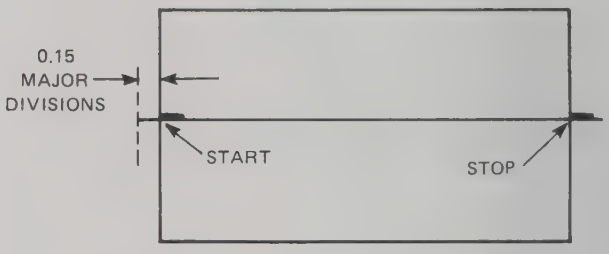


Figure 3-4b

3-4-4 NORMAL CENTER Adjustment

SET: A TIME/DIV .2 mS
VARIABLE CAL'D (Depressed)
HORIZ DISPLAY A

Connect a time marker generator to the CH-1 Input connector and set it for a 1 mS output. There should be three pulses displayed on the CRT.

Set the VARIABLE control to the X10 MAG position and adjust the HORIZ POS controls so that the control pulse is positioned on the center vertical graticule line.

Set the VARIABLE control to CAL'D position and adjust VR5 (T-2502) until the center pulse is positioned on the center vertical graticule line (see Figure 3-5).

3-5 TRIGGER CIRCUIT ADJUSTMENT

3-5-1 SLOPE BAL Adjustment

SET: A TIME/DIV .5 mS

Connect a sine wave generator to the CH-1 input connector and adjust at an output frequency of 1 kHz. Position

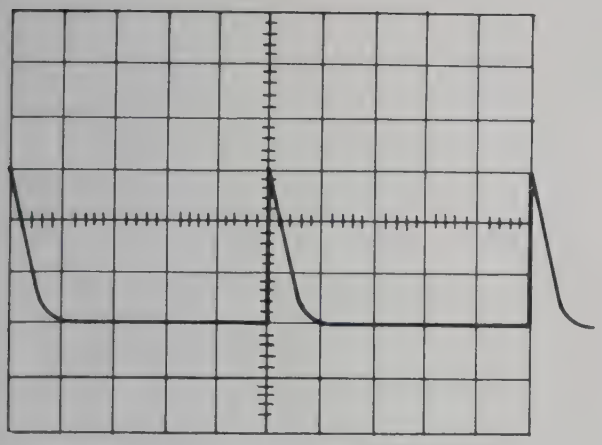


Figure 5

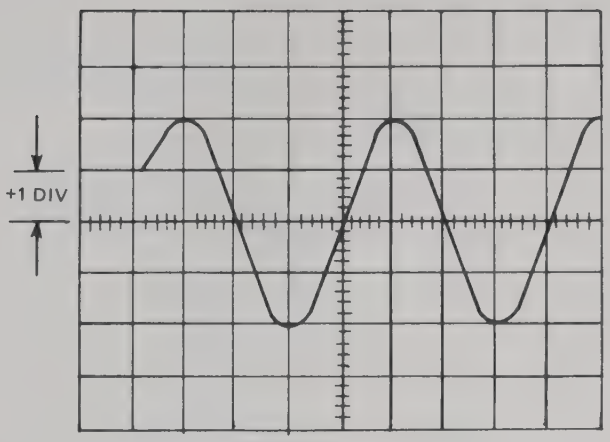


Figure 6

the center of the waveform with the center horizontal graticule line (ie., 2 divisions above and 2 divisions below). Adjust TRIG LEVEL so that displayed waveform starts at +1 Division (see figure 3-6).

Adjust SLOPE BAL VR8 (T-2502) so that the startpoint of the displayed waveform is +1 DIV when slope is changed to (+) or (–) see Figure 3-6.

3-5-2 TRIG LEVEL Adjustment

SET:	A TIME/DIV	0.5 mS
	TRIG LEVEL	0

Connect a sine wave generator to the CH-1 input generator and set the output frequency to 1 kHz at .5 division vertical deflection on the CRT.

Adjust VR7 (T-2502) so that displayed waveform is stable. When SLOPE switch is changed from (+) to (–).

3-5-3 PRESET Adjustment

SET:	A TIME/DIV	0.5 mS
	TRIG LEVEL	PRESET

Connect a sine wave generator to CH-1 Input connector and set the output at 1kHz at 0.5 division vertical deflection on CRT.

Adjust VR1 (T-2502) until vertical display remains stable.

3-6 EXTERNAL HORIZONTAL DISPLAY ADJUSTMENT

3-6-1 X GAIN Adjustment

SET:	A TIME/DIV	X-Y
	CH-1 VOLTS/DIV	5 mV
	VARIABLE	CAL'D

Connect an amplitude calibrator to the CH-1 Input connector (X-in) and set the output for 25 mV p-p.

Adjust VR7 (T-2554) for a horizontal deflection of 5 divisions.

4. REPLACEMENT PARTS LIST

LBO-525L MAIN FRAME

SCH. No.	Symbol No.	Description		
		CATHODE RAY TUBE		
3/10	V1		150CTB31	
		Filter	H-1532	
		ROTATOR COIL		
3/10	L1		L-600-3	
		LIGHT EMITIING DIODE		
2/10	D1	SLP-751		
		POWER TRANSFORMER		
2/10	PT1	J-488		
		CAPACITORS		
4/10	C1	Plastic	0.022 μF ±10%	630V
5/10	C101	Plastic	0.022 μF ±10%	630V
		RESISTORS		
4/10	R1	Carbon	1/4W 22Ω	±5%
5/10	R101	Carbon	1/4W 22Ω	±5%
4/10	R2	Carbon	1/4W 22Ω	±5%
5/10	R102	Carbon	1/4W 22Ω	±5%

SCH. No.	Symbol No.	Description	
		CONNECTORS	
3/10	J1	Type BNC Receptacle	BNC-080
3/10	J2	Terminal	E-307B
4/10	J3	Type BNC Receptacle	BNC-080
5/10	J4	Type BNC Receptacle	BNC-080
4/10	J5	Type BNC Receptacle	BNC-080
8/10	J6	Type BNC Receptacle	BNC-080
		Terminal	D-1376A
		Terminal	E-258A
		MISCELLANEOUS	
2/10	S1	Power Switch	SDG-5P-E
2/10	F1	Time Delay Fuse	ST-4 1A
		Fuseholder	FH-022
		Delay Time Mult. Dial	MG20-22B6
6/10		Delay Line	V-95
		ACCESSORIES	
		Probe	LP-050X

T-2502 TRIGGER AND SWEEP

SCH. No.	Symbol No.	Description		
		DIODES		
8/10	D1	Det	1S1588	35V
8/10	D2	Zener	RD5.1EB	5.1V
8/10	D3	Zener	RD5.1EB	5.1V
8/10	D4	Zener	RD5.1EB	5.1V
8/10	D5	Det	1S1588	35V
8/10	D6	Det	1S1588	35V
		INTEGRATED CIRCUITS		
8/10	IC1	HI-SPAC.	TB1	
8/10	IC2	HI-SPAC.	TB2	
8/10	IC3	TTL	74LS00	
8/10	IC4	TTL	74LS04	
9/10	IC5	TTL	74LS124	
9/10	IC6	TTL	74S74A	
9/10	IC7	TTL	74S00	
9/10	IC8	HI-SPAC.	SB1	
9/10	IC9	HI-SPAC.	LM361	
9/10	IC10	TTL	74S02	

SCH. No.	Symbol No.	Description	
9/10	IC11	TTL	74S74A
9/10	IC12	HI-SPAC.	SB1
10/10	IC13	CMOS	4066
10/10	IC14	CMOS	4011
10/10	IC15	HI-SPAC.	H1
		TRANSISTORS	
8/10	Q1	2SC1815-O or Y	
8/10	Q2	2SC1815-O or Y	
8/10	Q3	2SC1907	
8/10	Q4	2SC1815-O or Y	
9/10	Q5	2SC1907	
9/10	Q6	2SC1907	
9/10	Q7	2SC752-O	
9/10	Q8	2SC752-O	
10/10	Q9	2SC1815-O or Y	
10/10	Q10	2SD758	
10/10	Q11	2SD758	
10/10	Q12	2SC1819	
10/10	Q13	2SC1819	

SCH. No.	Symbol No.	Description			
		CAPACITORS			
8/10	C1	Mica	68 pF	±10%	500V
8/10	C2	Mica	18 pF	±10%	500V
8/10	C3	Mica	5 pF	±10%	500V
8/10	C4	Mica	18 pF	±10%	500V
8/10	C5	Mica	5 pF	±10%	500V
8/10	C6	Plastic	0.01 μF	±10%	50V
8/10	C7	Metal	0.01 μF	±20%	630V
8/10	C8	Electrolytic	10 μF		25V
8/10	C9	Ceramic	0.01 μF		50V
8/10	C10	Electrolytic	10 μF	BP	25V
8/10	C11	Ceramic	0.01 μF		50V
8/10	C12	Electrolytic	10 μF		25V
8/10	C13	Ceramic	0.1 μF		50V
8/10	C14	Ceramic	0.01 μF		50V
8/10	C15	Electrolytic	10 μF		25V
8/10	C16	Ceramic	0.01 μF		50V
8/10	C17	Electrolytic	10 μF	BP	25V
8/10	C18	Electrolytic	10 μF	BP	25V
8/10	C19	Plastic	0.039 μF	±10%	50V
8/10	C20	Ceramic	0.01 μF		50V
8/10	C21	Electrolytic	10 μF		25V
8/10	C22	Electrolytic	10 μF		25V
8/10	C23	Mica	22 pF		500V
8/10	C24	Ceramic	0.01 μF		50V
8/10	C25	Electrolytic	10 μF		24V
8/19	C26	Ceramic	0.01 μF		50V
	C27				
	C28				
	C29				
	C30				
	C31				
	C32				
	C33				
	C34				
	C35				
	C36				
	C37				
	C38				
	C39				
	C40				
9/10	C41	Ceramic	0.01 μF		50V
9/10	C42	Electrolytic	10 μF		25V
9/10	C43	Mica	5 pF	±10%	500V
9/10	C44	Mica	33 pF	±10%	500V
9/10	C45	Ceramic	0.01 μF		50V
9/10	C46	Electrolytic	10 μF		25V
9/10	C47	Electrolytic	4.7 μF		35V
9/10	C48	Electrolytic	10 μF		25V
9/10	C49	Ceramic	0.01 μF		50V
9/10	C50	Plastic	470 pF	±10%	50V
9/10	C51	Electrolytic	10 μF		25V
9/10	C52	Electrolytic	2.2 μF		50V
9/10	C53	Plastic	0.12 μF	±10%	50V
9/10	C54	Plastic	3900 pF	±10%	50V
9/10	C55	Ceramic	0.01 μF		50V
9/10	C56	Electrolytic	10 μF		25V
9/10	C57	Electrolytic	10 μF		25V
9/10	C58	Ceramic	0.01 μF		50V
9/10	C59	Electrolytic	10 μF		25V
9/10	C60	Ceramic	0.01 μF		50V

SCH. No.	Symbol No.	Description			
9/10	C61	Metal	1 μF	±2%	250V
9/10	C62	Plastic	0.082 μF	±10%	50V
9/10	C63	Plastic	1000 pF	±2%	125V
9/10	C64	Ceramic	0.1 μF		50V
9/10	C65	Ceramic	0.01 μF		50V
9/10	C66	Electrolytic	10 μF		25V
9/10	C67	Plastic	1000 pF	±2%	125V
9/10	C68	Mica	22 pF	±10%	50V
9/10	C69	Ceramic	0.01 μF		50V
9/10	C70	Ceramic	0.1 μF		50V
9/10	C71				
9/10	C72	Electrolytic	10 μF		25V
9/10	C73	Ceramic	0.01 μF		50V
9/10	C74	Mica	33 pF	±10%	500V
9/10	C75	Ceramic	0.01 μF		50V
9/10	C76	Mica	33 pF	±10%	500V
9/10	C77	Electrolytic	10 μF		25V
9/10	C78	Mica	56 pF	±10%	500V
	C79				
	C80				
	C81				
	C82				
	C83				
	C84				
	C85				
	C86				
	C87				
	C88				
	C89				
	C90				
	C91				
10/10	C92	Electrolytic	10 μF		25V
10/10	C93	Electrolytic	10 μF		25V
10/10	C94	Ceramic	0.01 μF		50V
10/10	C95	Electrolytic	10 μF		50V
	C96				
10/10	C97	Mica	180 pF	±10%	50V
10/10	C98	Ceramic	0.01 μF		50V
10/10	C99	Ceramic	0.01 μF		500V
10/10	C100	Electrolytic	10 μF		25V
10/10	C101	Ceramic	0.01 μF		50V
10/10	C102	Electrolytic	10 μF		25V
10/10	C103	Ceramic	0.01 μF		50V
10/10	C104	Electrolytic	10 μF		25V
10/10	C105	Ceramic	0.01 μF		50V
10/10	C106	Plastic	1500 pF	±10%	50V
10/10	C107	Plastic	1000 pF	±10%	50V
10/10	C108	Plastic	1500 pF	±10%	50V
10/10	C109	Mica	33 pF	±10%	50V
		VARIABLE CAPACITOR			
9/10	VC1	Ceramic	100 pF	CT882J	500V
		RESISTORS			
8/10	R1	Carbon	1/4W	680Ω	±5%
8/10	R2	Carbon	1/4W	8.2K	±5%
8/10	R3	Carbon	1/4W	8.2K	±5%
8/10	R4	Carbon	1/4W	220Ω	±5%
8/10	R5	Carbon	1/4W	1K	±5%

SCH. No.	Symbol No.	Description			
		RESISTORS			
8/10	R6	Carbon	1/2W	1M	±5%
8/10	R7	Carbon	1/4W	560K	±5%
8/10	R8	Carbon	1/4W	22K	±5%
8/10	R9	Carbon	1/4W	10K	±5%
8/10	R10	Carbon	1/4W	4.7K	±5%
8/10	R11	Carbon	1/4W	2.2K	±5%
8/10	R12	Carbon	1/4W	47Ω	±5%
8/10	R13	Carbon	1/4W	100Ω	±5%
8/10	R14	Carbon	1/4W	8.2K	±5%
8/10	R15	Carbon	1/4W	680Ω	±5%
8/10	R16	Carbon	1/4W	470K	±5%
8/10	R17	Carbon	1/4W	15K	±5%
8/10	R18	Carbon	1/4W	1.2K	±5%
8/10	R19	Carbon	1/4W	1.8K	±5%
8/10	R20	Carbon	1/4W	100K	±5%
8/10	R21	Carbon	1/4W	1K	±5%
	R22				
	R23				
	R24				
	R25				
	R26				
	R27				
	R28				
	R29				
	R30				
	R31				
	R32				
	R33				
	R34				
	R35				
	R36				
	R37				
	R38				
	R39				
	R40				
9/10	R41	Carbon	1/4W	100Ω	±5%
9/10	R42	Metal	1/4W	680Ω	±1%
9/10	R43	Metal	1/4W	910Ω	±1%
9/10	R44	Metal	1/4W	11K	±1%
9/10	R45	Metal	1/4W	2.4K	±1%
9/10	R46	Metal	1/4W	3.6K	±1%
9/10	R47	Carbon	1/4W	680Ω	±5%
9/10	R48	Carbon	1/4W	3.9K	±5%
9/10	R49	Carbon	1/4W	68K	±5%
9/10	R50	Carbon	1/4W	470Ω	±5%
9/10	R51	Carbon	1/4W	47K	±5%
9/10	R52	Carbon	1/4W	4.7K	±5%
9/10	R53	Carbon	1/4W	4.7K	±5%
9/10	R54	Carbon	1/4W	1.5K	±5%
9/10	R55	Metal	1/4W	4.7K	±1%
9/10	R56	Metal	1/4W	27K	±1%
9/10	R57	Carbon	1/4W	10K	±5%
9/10	R58	Carbon	1/4W	2.2K	±5%
9/10	R59	Metal	1/4W	15K	±1%
9/10	R60	Metal	1/4W	33K	±1%
9/10	R61	Carbon	1/4W	4.7K	±5%
9/10	R62	Carbon	1/4W	68K	±5%
9/10	R63	Metal	1/4W	5.1K	±1%
9/10	R64	Metal	1/4W	10K	±1%
9/10	R65	Carbon	1/4W	4.7K	±5%

SCH. No.	Symbol No.	Description			
9/10	R66	Carbon	1/4W	220K	±5%
9/10	R67	Carbon	1/4W	1.5K	±5%
9/10	R68	Carbon	1/4W	4.7K	±5%
9/10	R69	Carbon	1/4W	47Ω	±5%
9/10	R70	Carbon	1/4W	470Ω	±5%
9/10	R71	Carbon	1/4W	470Ω	±5%
	R72				
	R73				
	R74				
	R75				
	R76				
	R77				
	R78				
	R79				
	R80				
	R81				
10/10	R82	Carbon	1/4W	10K	±5%
10/10	R83	Carbon	1/4W	3.3k	±5%
10/10	R84	Carbon	1/4W	6.8K	±5%
10/10	R85				
10/10	R86	Carbon	1/4W	33K	±5%
10/10	R87	Carbon	1/4W	100K	±5%
10/10	R88	Carbon	1/4W	100K	±5%
10/10	R89	Carbon	1/4W	100K	±5%
	R90				
10/10	R91	Carbon	1/4W	2.2Ω	±5%
10/10	R92	Metal	1/4W	43Ω	±1%
	R93				
10/10	R94	Carbon	1/4W	18Ω	±5%
10/10	R95	Metal	1/4W	510Ω	±1%
10/10	R96	Carbon	1/4W	100Ω	±5%
10/10	R97	Carbon	1/4W	47Ω	±5%
10/10	R98	Carbon	1/4W	47Ω	±5%
10/10	R99	Metal	1/4W	910Ω	±1%
10/10	R100	Metal	1/4W	5.1K	±1%
10/10	R101	Carbon	1/4W	1K	±5%
10/10	R102	Carbon	1/4W	1K	±5%
10/10	R103	Metal	3W	18K	±5%
10/10	R104	Metal	3W	18K	±5%
10/10	R105	Carbon	1/4W	1K	±5%
10/10	R106	Carbon	1/4W	1K	±5%
		RESISTOR ARRAY			
8/10	RA1	EXB-P88	472K		
9/10	RA2	LRM2			
9/10	RA3	LRM2			
		VARIABLE RESISTORS			
8/10	VR1	Metal glaze	1/2W	22K	
9/10	VR2	V16L5(7x6.5) (PH2D) ZS (C301STPHD/ T3L123-3) 15 (3) S-B10K			
9/10	VR3	Metal glaze	1/2W	47K	
9/10	VR4	Metal glaze	1/2W	47K	
10/10	VR5	Metal glaze	1/2W	330Ω	
10/10	VR6	Metal glaze	1/2W	2.2K	
8/10	VR7	Metal glaze	0.3W	10K	
8/10	VR8	Metal glaze	0.3W	1K	
		COILS			
8/10	L1	Choke coil	22 μH	EL0606 220K	

SCH. No.	Symbol No.	Description
		SWITCHES
8/10	S1	Lever switch SLR-824
8/10	S2	Lever switch SLA-225
9/10	S3	Rotary switch S21P-2-3-20/1-1-11

SCH. No.	Symbol No.	Description
		PRINTED CIRCUIT BOARD
		T-2502B-R.P

T-2503 POWER SUPPLY & CRT

SCH. No.	Symbol No.	Description
		DIODES
2/10	D1	Bridge Rect. KBPS06
2/10	D2	Bridge Rect. W-04 400V
2/10	D3	Det 1S1588 35V
2/10	D4	Bridge Rect. W-02 200V
2/10	D5	Bridge Rect. W-02 200V
	D6	
	D7	
	D8	
	D9	
	D10	
3/10	D11	Det 1S1588 35V
3/10	D12	Det 1S1588 35V
3/10	D13	Det 1S1588 35V
3/10	D14	HV Rect ED3TV1 35V
3/10	D15	HV Rect ED3TV1 3KV
3/10	D16	Rect 1S2463 320V
3/10	D17	Rect 1S2463 320V
3/10	D18	Rect 1S2463 320V
3/10	D19	Rect 1S2463 320V
3/10	D20	Zener RD24EB 24V
3/10	D21	Zener RD24EB 24V
3/10	D22	Det 1S1588 35V
3/10	D23	Det 1S1588 35V
3/10	D24	Det 1S1588 35V
3/10	D25	Det 1S1588 35V
3/10	D26	Zener RD22EB 22V
	D27	
3/10	D28	Rect 1SS83 300V
	D29	
	D30	
	D31	
	D32	
		INTEGRATED CIRCUITS
2/10	IC1	Linear 1458
2/10	IC2	Regulator 7812
2/10	IC3	Regulator 7805
3/10	IC4	CMOS 4053
		TRANSISTORS
2/10	Q1	2SD859-O
2/10	Q2	2SC2551-O
2/10	Q3	2SC2551-O
2/10	Q4	2SA1015-O or Y
2/10	Q5	2SB435-Y

SCH. No.	Symbol No.	Description
2/10	Q6	2SC1815-O or Y
2/10	Q7	2SA10115-O or Y
2/10	Q8	2SB435-Y
	Q9	
	Q10	
3/10	Q11	2SD568
3/10	Q12	2SD1015-O or Y
3/10	Q13	2SC1815-O or Y
3/10	Q14	2SA1015-O or Y
3/10	Q15	2SC752G-TM-O
3/10	Q16	2SC752G-TM-O
3/10	Q17	2SC752G-TM-O
3/10	Q18	2SA1015-O or Y
3/10	Q19	2SC752G-TM-O
3/10	Q20	2SC1907
3/10	Q21	2SA1210-S or T
3/10	Q22	2SC2912 S or T
3/10	Q23	2SA1091-R
		CAPACITORS
2/10	C1	Electrolytic 33 μF 250V
2/10	C2	Electrolytic 33 μF 250V
2/10	C3	Electrolytic 220 μF 160V
2/10	C4	Electrolytic 220 μF 160V
2/10	C5	Mica 47 pF ±10% 500V
2/10	C6	Mica 47 pF ±10% 500V
2/10	C7	Electrolytic 4.7 μF 250V
2/10	C8	Electrolytic 2200 μF 35V
2/10	C9	Electrolytic 10 μF 25V
2/10	C10	Electrolytic 2200 μF 35V
2/10	C11	Electrolytic 1 μF 50V
2/10	C12	Electrolytic 1 μF 50V
2/10	C13	Electrolytic 10 μF 25V
2/10	C14	Plastic 0.1 μF ±10% 50V
	C15	
	C16	
	C17	
	C18	
	C19	
	C20	
	C21	
	C22	
	C23	
	C24	
	C25	

SCH. No.	Symbol No.	Description			
		CAPACITORS			
	C26				
	C27				
	C28				
	C29				
	C30				
3/10	C31	Electrolytic	47 μF		35V
3/10	C32	Plastic	0.12 μF	±10%	50V
3/10	C33	Electrolytic	10 μF		25V
3/10	C34	Ceramic	0.01 μF		50V
3/10	C35	Plastic	0.1 μF	±10%	50V
3/10	C36	Ceramic	470 pF		3KV
3/10	C37	Ceramic	0.0047 μF		3KV
3/10	C38	Ceramic	0.0047 μF		3KV
3/10	C39	Ceramic	0.0047 μF		3KV
3/10	C40	Ceramic	0.0047 μF		3KV
3/10	C41	Ceramic	0.0047 μF		3KV
3/10	C42	Ceramic	0.001 μF		500V
3/10	C43	Electrolytic	1 μF		250V
3/10	C44	Ceramic	0.0047 μF		3KV
	C45				
3/10	C46	Mica	12 pF	±10%	500V
	C47				
	C48				
3/10	C49	Ceramic	0.01 μF		50V
3/10	C50	Ceramic	0.01 μF		50V
3/10	C51	Ceramic	0.01 μF		50V
	C52				
3/10	C53	Ceramic	0.01 μF		50V
3/10	C54	Ceramic	0.1 μF		50V
3/10	C55	Mica	47 pF	±10%	500V
3/10	C56	Ceramic	0.75 pF		500V
3/10	C57	Ceramic	0.01 μF		500V
3/10	C58	Electrolytic	4.7 μF		160V
3/10	C59	Ceramic	0.01 μF		500V
3/10	C60	Ceramic	0.01 μF		500V
3/10	C61	Ceramic	0.01 μF		500V
3/10	C62	Ceramic	0.01 μF		50V
3/10	C63	Ceramic	0.01 μF		50V
		RESISTORS			
2/10	R1	Carbon	1/2W	68K	±5%
2/10	R2	Metal	1W	680Ω	±5%
2/10	R3	Metal	2W	8.2K	±5%
2/10	R4	Carbon	1/4W	820Ω	±5%
2/10	R5	Carbon	1/4W	12K	±5%
2/10	R6	Metal	1W	27K	±5%
2/10	R7	Carbon	1/4W	10K	±5%
2/10	R8	Carbon	1/4W	10K	±5%
2/10	R9	Metal	1/4W	91K	±1%
2/10	R10	Metal	1/4W	13K	±1%
2/10	R11	Carbon	1/4W	4.7K	±5%
2/10	R12	Carbon	1/2W	1.5Ω	±5%
2/10	R13	Metal	1W	330Ω	±5%
2/10	R14	Carbon	1/4W	10K	±5%
2/10	R15	Metal	1/4W	10K	±1%

SCH. No.	Symbol No.	Description			
2/10	R16	Metal	1/4W	10K	±1%
2/10	R17	Metal	2W	27Ω	±5%
2/10	R18	Carbon	1/4W	1.2M	±5%
2/10	R19	Carbon	1/4W	470K	±5%
2/10	R20	Carbon	1/4W	1K	±5%
2/10	R21	Carbon	1/2W	1Ω	±5%
2/10	R22	Metal	1W	15Ω	±5%
2/10	R23	Carbon	1/4W	1.8M	±5%
	R24				
	R25				
	R26				
	R27				
	R28				
	R29				
	R30				
	R31				
	R32				
	R33				
	R34				
	R35				
	R36				
	R37				
	R38				
	R39				
	R40				
3/10	R41	Carbon	1/2W	2.2Ω	±5%
3/10	R42	Carbon	1/4W	68Ω	±5%
3/10	R43	Carbon	1/4W	22Ω	±5%
3/10	R44	Carbon	1/4W	1.5K	±5%
3/10	R46	Carbon	1/4W	1K	±5%
3/10	R47	Carbon	1/4W	100Ω	±5%
3/10	R48	Carbon	1/4W	5.6K	±5%
3/10	R49	Carbon	1/4W	3.9K	±5%
3/10	R50	Carbon	1/4W	56K	±5%
3/10	R51	Metal glaze	1W	22M	±5%
3/10	R52	Carbon	1/2W	47K	±5%
3/10	R53	Carbon	1/4W	330K	±5%
3/10	R54	Carbon	1/4W	22K	±5%
3/10	R55	Carbon	1/4W	47K	±5%
3/10	R56	Metal glaze	1/2W	10M	±10%
3/10	R57	Metal glaze	1/2W	5.6M	±10%
3/10	R58	Metal glaze	1W	10M	±5%
3/10	R59	Carbon	1/2W	1.8M	±5%
3/10	R60	Carbon	1/4W	120K	±5%
3/10	R61	Carbon	1/4W	22K	±5%
3/10	R62	Carbon	1/4W	4.7K	±5%
3/10	R63	Carbon	1/4W	560Ω	±5%
3/10	R64	Carbon	1/4W	1K	±5%
3/10	R65	Carbon	1/4W	1.5K	±5%
3/10	R66	Carbon	1/4W	1K	±5%
3/10	R67	Carbon	1/4W	1K	±5%
3/10	R68	Carbon	1/4W	1.5K	±5%
3/10	R69	Carbon	1/4W	1K	±5%
3/10	R70	Carbon	1/4W	1K	±5%

SCH. No.	Symbol No.	Description
		RESISTORS
3/10	R71	Carbon 1/4W 6.8K ±5%
3/10	R72	Carbon 1/4W 1K ±5%
3/10	R73	Carbon 1/4W 1.8K ±5%
3/10	R74	Carbon 1/4W 1.8K ±5%
3/10	R75	Carbon 1/4W 6.8K ±5%
3/10	R76	Carbon 1/4W 2.2K ±5%
3/10	R77	Carbon 1/4W 8.2K ±5%
3/10	R78	Carbon 1/4W 3.9K ±5%
3/10	R79	Carbon 1/4W 4.7K ±5%
3/10	R80	Carbon 1/4W 3.9K ±5%
3/10	R81	Carbon 1/4W 47Ω ±5%
3/10	R82	Carbon 1/4W 56K ±5%
3/10	R83	Metal 1W 22K ±5%
3/10	R84	Carbon 1/4W 470Ω ±5%
3/10	R85	Carbon 1/4W 47Ω ±5%
3/10	R86	Carbon 1/4W 100Ω ±5%
3/10	R87	Carbon 1/4W 1.5K ±5%
3/10	R88	Carbon 1/4W 100K ±5%
3/10	R89	Carbon 1/4W 12K ±5%
3/10	R90	Carbon 1/4W 1.5K ±5%

SCH. No.	Symbol No.	Description
3/10	R91	Carbon 1/2W 33K ±5%
3/10	R92	Carbon 1/4W 1.8Ω ±5%
3/10	R93	Carbon 1/4W 390Ω ±5%
3/10	R94	Metal 2W 8.2K ±5%
		VARIABLE RESISTORS
3/10	VR1	Metal glaze 1/2W 47K Intent
3/10	VR2	Metal glaze 1/2W 22K H Volt
3/10	VR3	V16L4 (7 x 6) (PH2A) 15 (3) S-B2M Focus
3/10	VR4	Metal glaze 1/2W 220K Astig
		TRANSFORMER
3/10	T1	High Voltage Transformer J-490
		FUSE
3/10	F1	0.5A 5.2 x 20 mm Fast Blow
		FUSE HOLDER
3/10		S-N5053
		NEON LAMP
3/10	V1	NE-38B
3/10	V2	NE-38B
3/10	V3	NE-38B
		PRINTED CIRCUIT BOARD
2/10 3/10		T-2503B-R.P

T-2504 VERTICAL MODE SWITCHING

SCH. No.	Symbol No.	Description
		CAPACITORS
4/10	C1	Ceramic 0.01 μF 50V
5/10	C2	Ceramic 0.01 μF 50V
6/10	C3	Ceramic 0.01 μF 50V
		VARIABLE RESISTORS
4/10	VR1	V16L4 (7 x 6.5) (PH2D) 15 (3) S-B5K
5/10	VR2	V16L4 (7 x 6.5) (PH2D) 15 (3) S-B5K

SCH. No.	Symbol No.	Description
		SWITCHES
5/10	S1	Push Q-469
6/10	S2	Lever SLA-225
		PRINTED CIRCUIT BOARD
4/10 5/10 6/10		T-2504A-R.P

T-2505 TRIGGER AMPLIFIER

SCH. No.	Symbol No.	Description
		RESISTOR
2/10	R1	Carbon 1/4W 330Ω ±5%
		VARIABLE RESISTORS
8/10	VR1/ S1	V16L5 (7 x 6.5) (PH2D) S (C301 MTP HD1 + SL123-3) 15 (3) S-B10K
9/10	VR2/ S2	V16L4 (7 x 6.5) (PH2D) S (C26MGP HD-2) 15 (3) S-B100K

SCH. No.	Symbol No.	Description
		PRINTED CIRCUIT BOARD
2/10 8/10 9/10		T-2505A-R.P

T-2506 ILLUM

SCH. No.	Symbol No.	Description
		LAMPS
2/10	V1	6.3V, 200 mA, A-53632
2/10	V2	6.3V, 200 mA, A-53632
2/10	V3	6.3V, 200 mA, A-53632

SCH. No.	Symbol No.	Description
		PRINTED CIRCUIT BOARD
2/10		T-2506A-R.P

T-2507 H. MODE

SCH. No.	Symbol No.	Description
		CAPACITORS
9/10	C1	Ceramic 0.01 μF 50V
10/10	C2	Ceramic 0.01 μF 50V
10/10	C3	Ceramic 0.01 μF 50V
		RESISTORS
9/10	R1	Carbon 1/4W 5.6K ±5%
9/10	R2	Carbon 1/4W 39Ω ±5%
10/10	R3	Carbon 1/4W 1K ±5%
10/10	R4	Carbon 1/4W 82K ±5%
10/10	R5	Metal 1/4W 9.1K ±1%
		VARIABLE RESISTORS
9/10	VR1	Metal glaze 1/2W 10K
9/10	VR2	Wire wound 22HP-10-5K

SCH. No.	Symbol No.	Description
9/10	VR3	Metal glaze 1/2W 220Ω
10/10	VR4	V16L5 (9 x 6.5) D (PH2D) N15 (3) S 15 (6) R-B10KΩ x 10 KΩ
		SWITCHES
8/10	S1	Push SUN-1 Q-470
9/10	S2	Push SUN-40 Q-468
		PRINTED CIRCUIT BOARD
8/10		T-2507-R.P

T-2508 INTEN

SCH. No.	Symbol No.	Description
		INTEGRATED CIRCUIT
3/10	IC1	HI-Spac. C1
		CAPACITORS
3/10	C1	Electrolytic 47 μF 10V
3/10	C2	Plastic 0.0068 μF ±22% 50V
3/10	C3	Plastic 0.0068 μF ±22% 50V
3/10	C4	Electrolytic 10 μF 25V
3/10	C5	Electrolytic 10 μF 25V

SCH. No.	Symbol No.	Description
		RESISTORS
3/10	R1	Carbon 1/4W 3.3K ±5%
3/10	R2	Metal 1/4W 100K ±1%
3/10	R3	Carbon 1/4W 8.2K ±5%
3/10	R4	Metal 1/4W 100K ±1%
3/10	R5	Carbon 1/4W 390Ω ±5%
		VARIABLE RESISTORS
2/10	VR1	V16L4 (7 x 6.5) (PH2D) 15 (3) S-B10K
3/10	VR2	V16L4 (7 x 6.5) (PH2D) 15 (3) S-B10K
	VR3	
3/10	VR4	V16L4 (7 x 6.5) (PH2D) 15 (3) S-B10K
3/10	VR5	TM62KPV-B470
		PRINTED CIRCUIT BOARD
3/10		T-2508A-R.P

T-2509 CRT SOCKET

SCH. No.	Symbol No.	Description
		CAPACITORS
3/10	C1	Ceramic 0.001 μF 500V
3/10	C2	Ceramic 0.01 μF 500V
		COILS
3/10	L1	Choke coil 0.82 μH ±10%
3/10	L2	Choke coil 0.82 μH ±10%

SCH. No.	Symbol No.	Description
		CRT SOCKET
		No. 1339
		PRINTED CIRCUIT BOARD
3/10		T-2509B-R.P

SCH. No.	Symbol No.	Description		
		SWITCHES		
4/10	S1	Lever	SLM-723	
5/10	S101	Lever	SLM-723	

SCH. No.	Symbol No.	Description
		PRINTED CIRCUIT BOARD
4/10		T-2514-R.P
5/10		T-2514-R.P

T-3003 VERTICAL PREAMPLIFIERS

SCH. No.	Symbol No.	Description			
		DIODES			
4/10	D1	Det.	30V	MC931	
4/10	D2	Det.	30V	MC931	
4/10	D3	Det.	35V	1S1588	
4/10	D4	Det.	35V	1S1588	
4/10	D5	Det.	35V	1S1588	
5/10	D101	Det.	30V	MC931	
5/10	D102	Det.	30V	MC931	
		INTEGRATED CIRCUITS			
4/10	IC1	HI Spac	VB1		
4/10	IC2	HI Spac	VB2		
4/10	IC3	HI Spac	VB3		
5/10	IC101	HI Spac	VB1		
5/10	IC102	HI Spac	VB2		
5/10	IC103	HI Spac	VB3		
6/10	IC201	HI Spac	VB5		
6/10	IC202	TTL	74LS123		
6/10	IC203	TTL	74LS123		
6/10	IC204	TTL	74LS10		
6/10	IC205	TTL	74LS00		
6/10	IC206	TTL	74LS74A		
		TRANSISTORS			
4/10	Q1	2SC1907			
4/10	Q2	2SA781			
6/10	Q207	2SA1015-O or Y			
6/10	Q208	2SC1815-O or Y			
6/10	Q211	2SC1917			
6/10	Q212	2SC1917			
		CAPACITORS			
4/10	C1	Mica	100 pF	±10%	500V
4/10	C2	Mica	68 pF	±10%	500V
4/10	C3	Mica	3 pF	±10%	500V
4/10	C4	Mica	27 pF	±10%	500V
4/10	C5	Plastic	0.01 μF	±10%	630V
4/10	C6	Electrolytic	10 μF		25V
4/10	C7	Mica	22 pF	±10%	500V
4/10	C9	Mica	47 pF	±10%	500V
4/10	C10	Mica	27 pF	±10%	500V
4/10	C11	Mica	3 pF	±10%	500V
4/10	C12	Mica	3 pF	±10%	500V
4/10	C13	Ceramic	0.01 μF		50V
4/10	C14	Ceramic	0.01 μF		50V
4/10	C15	Electrolytic	100 μF		16V
4/10	C16	Ceramic	0.01 μF		50V
4/10	C17	Ceramic	0.01 μF		50V
4/10	C18	Electrolytic	100 μF		16V
4/10	C19	Mica	3 pF	±10%	500V
4/10	C20	Ceramic	0.01 μF		50V

SCH. No.	Symbol No.	Description			
4/10	C21	Electrolytic	10 μF		25V
4/10	C22	Ceramic	0.01 μF		50V
4/10	C23	Electrolytic	10 μF		25V
4/10	C24	Mica	33 pF	±10%	500V
4/10	C25	Plastic	220 pF	±10%	50V
4/10	C26	Mica	47 pF	±10%	50V
4/10	C27	Mica	1 pF	±10%	50V
4/10	C28	Electrolytic	10 μF		25V
4/10	C29	Ceramic	0.01 μF		50V
4/10	C30	Ceramic	0.01 μF		50V
4/10	C31	Electrolytic	10 μF		25V
4/10	C32	Mica	56 pF	±10%	500V
8/10	C33	Mica	7 pF	±10%	500V
8/10	C34	Mica	10 pF	±10%	500V
8/10	C35	Mica	5 pF	±10%	500V
8/10	C36	Mica	5 pF	±10%	500V
5/10	C101	Mica	100 pF	±10%	500V
5/10	C102	Mica	68 pF	±10%	500V
5/10	C103	Mica	3 pF	±10%	500V
5/10	C104	Mica	27 pF	±10%	500V
5/10	C105	Plastic	0.01 μF	±10%	630V
5/10	C106	Electrolytic	10 μF		25V
5/10	C107	Mica	22 pF	±10%	500V
5/10	C108	Ceramic	0.01 μF		50V
5/10	C109	Mica	3 pF	±10%	500V
5/10	C110	Mica	10 pF	±10%	500V
5/10	C111	Mica	5 pF	±10%	500V
5/10	C112				
5/10	C113	Ceramic	0.01 μF		50V
5/10	C114				
5/10	C115	Electrolytic	100 μF		16V
5/10	C116	Electrolytic	33 μF		16V
5/10	C117	Ceramic	0.01 μF		50V
5/10	C118	Electrolytic	100 μF		16V
5/10	C119	Electrolytic	33 μF		16V
5/10	C120	Ceramic	0.01 μF		50V
5/10	C121	Electrolytic	10 μF		25V
5/10	C122	Ceramic	0.01 μF		50V
5/10	C123	Electrolytic	10 μF		25V
5/10	C124	Mica	33 pF	±10%	500V
5/10	C125	Mica	47 pF	±10%	500V
5/10	C127	Plastic	220 pF	±10%	50V
5/10	C128	Ceramic	0.01 μF		50V
5/10	C129	Mica	12 pF	±10%	500V
5/10	C130	Mica	5 pF	±10%	500V

SCH. No.	Symbol No.	Description			
		CAPACITORS			
5/10	C131	Mica	7 pF	±10%	500V
5/10	C132	Mica	10 pF	±10%	500V
5/10	C133	Mica	5 pF	±10%	500V
5/10	C134	Mica	5 pF	±10%	500V
6/10	C201	Mica	3 pF	±10%	500V
6/10	C206	Ceramic	0.01 μF		50V
6/10	C211	Ceramic	0.01 μF		50V
6/10	C212	Ceramic	0.01 μF		50V
	C213				
6/10	C214	Mica	22 pF	±10%	500V
6/10	C215	Mica	100 pF	±10%	50V
6/10	C216	Ceramic	0.01 μF		50V
6/10	C217	Ceramic	0.01 μF		50V
6/10	C218	Ceramic	0.01 μF		50V
6/10	C219	Mica	100 pF	±10%	50V
6/10	C220	Mica	100 pF	±10%	50V
6/10	C221	Ceramic	0.01 μF		50V
	C222				
	C223				
6/10	C224	Ceramic	0.01 μF		50V
	C225				
	C226				
6/10	C227		0.001 μF		50V
		VARIABLE CAPACITORS			
4/10	VC1	Ceramic	10 pF		500V
4/10	VC2	Ceramic	6 pF		500V
4/10	VC3	Ceramic	10 pF		500V
4/10	VC4	Ceramic	6 pF		500V
4/10	VC5	Ceramic	10 pF		500V
4/10	VC6	Ceramic	6 pF		500V
4/10	VC7	Ceramic	10 pF		500V
4/10	VC8	Ceramic	6 pF		500V
4/10	VC10	Ceramic	20 pF		500V
4/10	VC11	Ceramic	40 pF		500V
5/10	VC101	Ceramic	10 pF		500V
5/10	VC102	Ceramic	6 pF		500V
5/10	VC103	Ceramic	10 pF		500V
5/10	VC104	Ceramic	6 pF		500V
5/10	VC105	Ceramic	10 pF		500V
5/10	VC106	Ceramic	6 pF		500V
5/10	VC107	Ceramic	10 pF		500V
5/10	VC108	Ceramic	6 pF		500V
5/10	VC110	Ceramic	20 pF		500V
5/10	VC111	Ceramic	40 pF		500V
5/10	VC112	Ceramic	40 pf		500V
		RESISTORS			
4/10	R1	Carbon	1/4W	22Ω	±5%
4/10	R2	Carbon	1/4W	22Ω	±5%
4/10	R3	Metal	1/2W	900K	±0.5%
4/10	R4	Metal	1/4W	11iK	±0.5%
4/10	R5	Metal	1/2W	990K	±0.5%

SCH. No.	Symbol No.	Description			
4/10	R6	Metal	1/4W	10.1K	±0.5%
4/10	R7	Metal	1/2W	600K	±0.5%
4/10	R8	Metal	1/4W	667K	±0.5%
4/10	R9	Metal	1/2W	800K	±0.5%
4/10	R10	Metal	1/4W	250K	±0.5%
4/10	R11	Metal	1/2W	1M	±0.5%
4/10	R12	Metal	1/2W	330K	±0.5%
4/10	R13	Carbon	1/6W	270Ω	±5%
4/10	R14	Metal	1/4W	1.8K	±1%
4/10	R15	Carbon	1/6W	150Ω	±5%
4/10	R16	Carbon	1/6W	33K	±5%
4/10	R17	Carbon	1/6W	220K	±5%
4/10	R18	Metal	1/4W	6.8K	±0.5%
4/10	R19	Metal	1/4W	1M	±0.5%
4/10	R20	Metal	1/4W	3.3K	±0.5%
4/10	R21	Metal	1/4W	240Ω	±0.5%
4/10	R22	Carbon	1/6W	3.3Ω	±5%
4/10	R23	Carbon	1/6W	10Ω	±5%
4/10	R24	Carbon	1/6W	100Ω	±5%
4/10	R25	Metal	1/4W	470Ω	±1%
4/10	R26	Carbon	1/6W	1K	±5%
4/10	R27	Carbon	1/6W	4.7Ω	±5%
4/10	R28	Carbon	1/6W	4.7Ω	±5%
4/10	R29	Carbon	1/6W	820Ω	±5%
4/10	R30	Carbon	1/6W	100Ω	±5%
4/10	R31	Carbon	1/6W	4.7K	±5%
	R32				
4/10	R33	Carbon	1/6W	0Ω	±5%
4/10	R34	Carbon	1/6W	0Ω	±5%
4/10	R35	Carbon	1/6W	180Ω	±5%
4/10	R36	Metal	1/4W	47K	±1%
4/10	R37	Carbon	1/6W	56K	±5%
4/10	R38	Carbon	1/6W	33K	±5%
4/10	R39	Carbon	1/6W	33Ω	±5%
4/10	R40	Carbon	1/6W	10Ω	±5%
4/10	R41	Carbon	1/6W	150Ω	±5%
4/10	R42	Carbon	1/6W	27Ω	±5%
4/10	R43	Metal	1/4W	2K	±1%
4/10	R44	Metal	1/4W	470Ω	±1%
4/10	R45	Metal	1/4W	3.9K	±1%
4/10	R46	Carbon	1/6W	390Ω	±5%
4/10	R47	Carbon	1/6W	22Ω	±5%
4/10	R48	Carbon	1/6W	22Ω	±5%
4/10	R49	Carbon	1/6W	39Ω	±5%
4/10	R50	Carbon	1/6W	390Ω	±5%
5/10	R101	Carbon	1/6W	22Ω	±5%
5/10	R102	Carbon	1/6W	22Ω	±5%
5/10	R103	Metal	1/2W	900K	±0.5%
5/10	R104	Metal	1/4W	111K	±0.5%
5/10	R105	Metal	1/2W	990K	±0.5%
5/10	R106	Metal	1/4W	10.1K	±0.5%
5/10	R107	Metal	1/2W	600K	±0.5%
5/10	R108	Metal	1/4W	667K	±0.5%
5/10	R109	Metal	1/2W	800K	±0.5%
5/10	R110	Metal	1/4W	250K	±0.5%
5/10	R111	Metal	1/2W	1M	±0.5%
5/10	R112	Metal	1/2W	330K	±1%
5/10	R113	Carbon	1/6W	10Ω	±5%
5/10	R114	Metal	1/4W	1.8K	±1%
5/10	R115	Carbon	1/6W	150Ω	±5%

SCH. No.	Symbol No.	Description			
		RESISTORS			
5/10	R116	Carbon	1/6W	33K	±5%
5/10	R117	Carbon	1/6W	220K	±5%
5/10	R118	Metal	1/4W	6.8K	±0.5%
5/10	R119	Metal	1/4W	1M	±0.5%
5/10	R120	Metal	1/4W	3.3K	±0.5%
5/10	R121	Metal	1/4W	240Ω	±0.5%
5/10	R122	Carbon	1/6W	3.3Ω	±5%
5/10	R123	Carbon	1/6W	10Ω	±5%
5/10	R124	Carbon	1/6W	0Ω	±5%
5/10	R125	Metal	1/4W	470Ω	±1%
5/10	R126	Carbon	1/6W	1K	±5%
5/10	R127	Carbon	1/6W	220Ω	±5%
5/10	R128	Carbon	1/6W	4.7Ω	±5%
5/10	R129	Carbon	1/6W	5.6Ω	±5%
5/10	R130	Carbon	1/6W	3.3K	±5%
5/10	R131				
	R132				
5/10	R133	Carbon	1/6W	0Ω	±5%
5/10	R134				
5/10	R135	Carbon	1/6W	180Ω	±5%
5/10	R136	Metal	1/4W	47K	±1%
5/10	R137	Carbon	1/6W	56K	±5%
5/10	R138	Carbon	1/6W	33K	±5%
5/10	R139	Carbon	1/6W	33Ω	±5%
5/10	R140	Carbon	1/6W	10Ω	±5%
5/10	R141	Carbon	1/6W	56Ω	±5%
5/10	R142	Metal	1/4W	360Ω	±1%
6/10	R201	Metal	1/2W	390Ω	±1%
6/10	R202	Metal	1/2W	750Ω	±1%
6/10	R203	Metal	1/2W	390Ω	±1%
6/10	R204	Carbon	1/6W	47K	±5%
6/10	R205	Metal	1/4W	91Ω	±1%
6/10	R206	Metal	1/4W	91Ω	±1%
6/10	R207	Metal	1/2W	820Ω	±1%
	R208				
	R209				
	R210				
	R211				
	R212				
	R213				
	R214				
	R215				
	R216				
	R217				
	R218				
	R219				
	R220				

SCH. No.	Symbol No.	Description			
	R221				
	R222				
	R223				
	R224				
	R225				
	R226				
6/10	R227	Carbon	1/6W	5.6K	±5%
6/10	R228	Carbon	1/6W	5.6K	±5%
6/10	R229	Carbon	1/6W	27K	±5%
6/10	R230	Carbon	1/6W	10K	±5%
6/10	R231	Carbon	1/6W	4.7K	±5%
6/10	R232	Carbon	1/6W	22K	±5%
		RESISTOR ARRAY			
4/10	RA1	LRM-1			
5/10	RA101	LRM-1			
6/10	RA102	EXB-P86	472K		
		VARIABLE RESISTORS			
4/10	VR1	Metal glaze	0.3W	500Ω	
4/10	VR2	Metal glaze	0.3W	100Ω	
4/10	VR3	Metal glaze	0.3W	10K	
4/10	VR4	Ganged with S2			
4/10	VR5	Metal glaze	0.3W	50K	
4/10	VR6	Metal glaze	0.3W	200Ω	
4/10	VR7	Metal glaze	0.3W	5K	
4/10	VR8	Metal glaze	0.3W	200Ω	
4/10	VR9	Metal glaze	0.3W	500Ω	
5/10	VR101	Metal glaze	0.3W	500Ω	
5/10	VR102	Metal glaze	0.3W	100Ω	
5/10	VR103	Metal glaze	0.3W	10K	
5/10	VR104	Ganged with S102			
5/10	VR105	Metal glaze	0.3W	50K	
5/10	VR106	Metal glaze	0.3W	200Ω	
5/10	VR107	Metal glaze	0.3W	5K	
5/10	VR108	Metal glaze	0.3W	200Ω	
		VERTICAL ATTENUATORS			
4/10	S2	S21P-4-4-10/RV, Q509			
5/10	S102	S21P-4-4-10/RV, Q509			
		PRINTED CIRCUIT BOARD			
4/10		T-3003-R.P			
5/10					
6/10					

T-3004 VERTICAL FINAL AMP

SCH. No.	Symbol No.	Description			
		DIODE			
7/10	D1	Zener	3V	RD3.0EB	
		TRANSISTORS			
7/10	Q1	2SA781			
7/10	Q2	2SA781			
7/10	Q3	2SC1907			
7/10	Q4	2SC1907			
7/10	Q5	2SC1907			
7/10	Q6	2SC1907			
7/10	Q7	2SC1907			
7/10	Q8	2SC1907			
7/10	Q9	2SC2851			
7/10	Q10	2SC2851			
7/10	Q11	2SC2911			
7/10	Q12	2SC2911			
		CAPACITORS			
7/10	C1	Mica	5 pF	±10%	500V
7/10	C2	Mica	3 pF	±10%	500V
7/10	C3	Mica	1 pF	±10%	500V
7/10	C4	Ceramic	0.01 μF		50V
7/10	C5	Ceramic	0.01 μF		50V
7/10	C6	Mica	82 pF	±10%	500V
7/10	C7	Mica	0.01 μF		500V
7/10	C8	Mica	0.01 μF		50V
	C9				
7/10	C10	Mica	0.01 μF		50V
7/10	C11	Electrolytic	10 μF		25V
7/10	C12	Ceramic	0.01 μF		50V
7/10	C13	Electrolytic	10 μF		25V
	C14				
7/10	C15	Electrolytic	4.7 μF		160V
7/10	C16	Ceramic	0.01 μF		50V
7/10	C17	Ceramic	0.01 μF		50V
7/10	C18	Electrolytic	10 μF		25V
7/10	C19	Mica	10 pF	±10%	500V
7/10	C20	Mica	2 pF	±10%	500V
7/10	C21	Mica	3 pF	±10%	500V
7/10	C22	Mica	3 pF	±10%	500V
7/10	C23	Mica	100 pF	±10%	500V
		VARIABLE CAPACITORS			
7/10	VC1	Ceramic	40 pF		500V
7/10	VC2	Ceramic	40 pF		500V
		RESISTORS			
7/10	R1	Metal	1/4W	220Ω	±1%
7/10	R2	Carbon	1/6W	47Ω	±5%
7/10	R3	Carbon	1/6W	1K	±5%
7/10	R4	Carbon	1/6W	47Ω	±5%
7/10	R5	Metal	1/4W	240Ω	±5%
7/10	R6	Carbon	1/6W	1.2K	±5%
7/10	R7	Carbon	1/6W	1.2K	±5%

SCH. No.	Symbol No.	Description			
7/10	R8	Metal	1/4W	240Ω	±1%
7/10	R9	Metal	1/4W	240Ω	±1%
7/10	R10	Carbon	1/6W	47Ω	±5%
7/10	R11	Carbon	1/6W	47Ω	±5%
7/10	R12	Metal	1/4W	330Ω	±1%
7/10	R13	Carbon	1/6W	2.2K	±5%
7/10	R14	Carbon	1/6W	2.2K	±5%
7/10	R15	Carbon	1/6W	22Ω	±5%
7/10	R16	Carbon	1/6W	22Ω	±5%
7/10	R17	Carbon	1/6W	47Ω	±5%
7/10	R18	Carbon	1/6W	47Ω	±5%
7/10	R19	Carbon	1/6W	2.7K	±5%
7/10	R20	Carbon	1/6W	1.2K	±5%
7/10	R21	Metal	1/4W	620Ω	±1%
7/10	R21	Metal	1/4W	620Ω	±1%
7/10	R22	Metal	1/4W	620Ω	±1%
7/10	R23	Carbon	1/6W	47Ω	±5%
7/10	R24	Carbon	1/6W	47Ω	±5%
7/10	R25	Carbon	1/2W	3.9K	±5%
7/10	R26	Carbon	1/2W	3.9K	±5%
7/10	R27	Carbon	1/4W	47Ω	±5%
7/10	R28	Carbon	1/4W	47Ω	±5%
7/10	R29	Metal	1/2W	180Ω	±1%
7/10	R30	Metal	1/2W	180Ω	±1%
7/10	R31	Metal	1/2W	270Ω	±1%
7/10	R32	Metal	1/2W	270Ω	±1%
7/10	R33	Metal	1/2W	240Ω	±1%
7/10	R34	Metal	1/2W	240Ω	±1%
7/10	R35	Carbon	1/6W	15Ω	±5%
7/10	R36	Carbon	1/6W	15Ω	±5%
7/10	R37	Carbon	1/6W	22Ω	±5%
7/10	R38	Carbon	1/6W	22Ω	±5%
7/10	R39	Metal	1W	15K	±5%
7/10	R40	Metal	5W	330Ω	±5%
7/10	R41	Metal	5W	330Ω	±5%
7/10	R42	Metal	5W	330Ω	±5%
7/10	R43	Metal	5W	330Ω	±5%
7/10	R44	Carbon	1/6W	3.9KΩ	±5%
7/10	R45	Carbon	1/6W	100Ω	±5%
7/10	R46	Carbon	1/6W	3.9Ω	±5%
		VARIABLE RESISTORS			
7/10	VR1	Metal glaze	0.3W	10K	
7/10	VR2	Metal glaze	0.3W	100Ω	
		COILS			
7/10	L1	Choke coil	100 μH	EL060	101K
7/10	L2	Choke coil	100 μH	SF-78-50D	
		PRINTED CIRCUIT BOARD			
7/10		T-3004-R.P			

T-3005 MULTIPLIER

SCH. No.	Symbol No.	Description			
		RESISTOR			
3/10	R1	Carbon	1/4W	470K	±5%
		MULTIPLIER			
3/10	SA1	MR4A-7F			

SCH. No.	Symbol No.	Description
		PRINTED CIRCUIT BOARD
3/10		T-3005-R.P

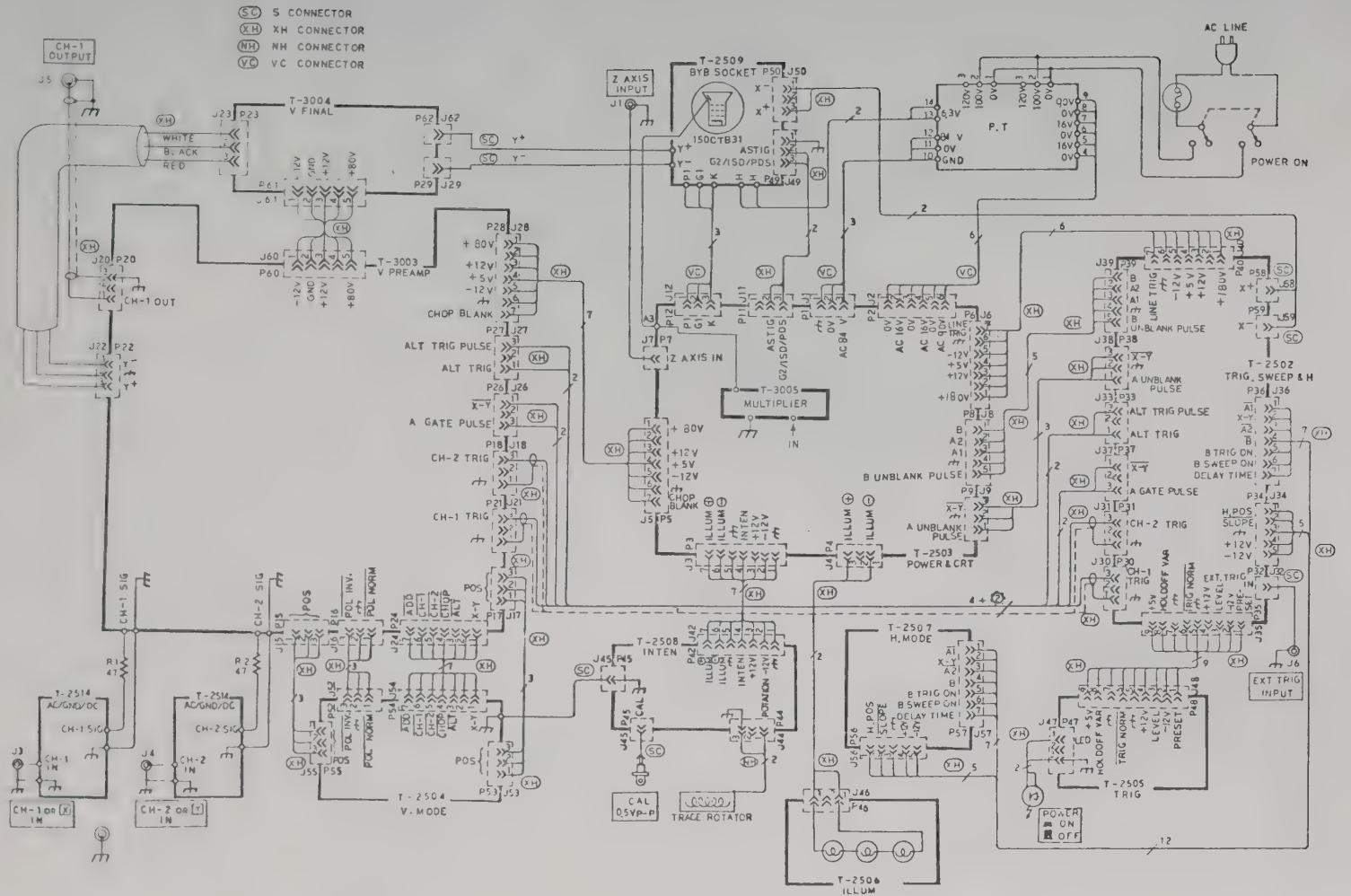


Figure 5-1. LBO-525L Interconnection (Schematic 1 of 10)

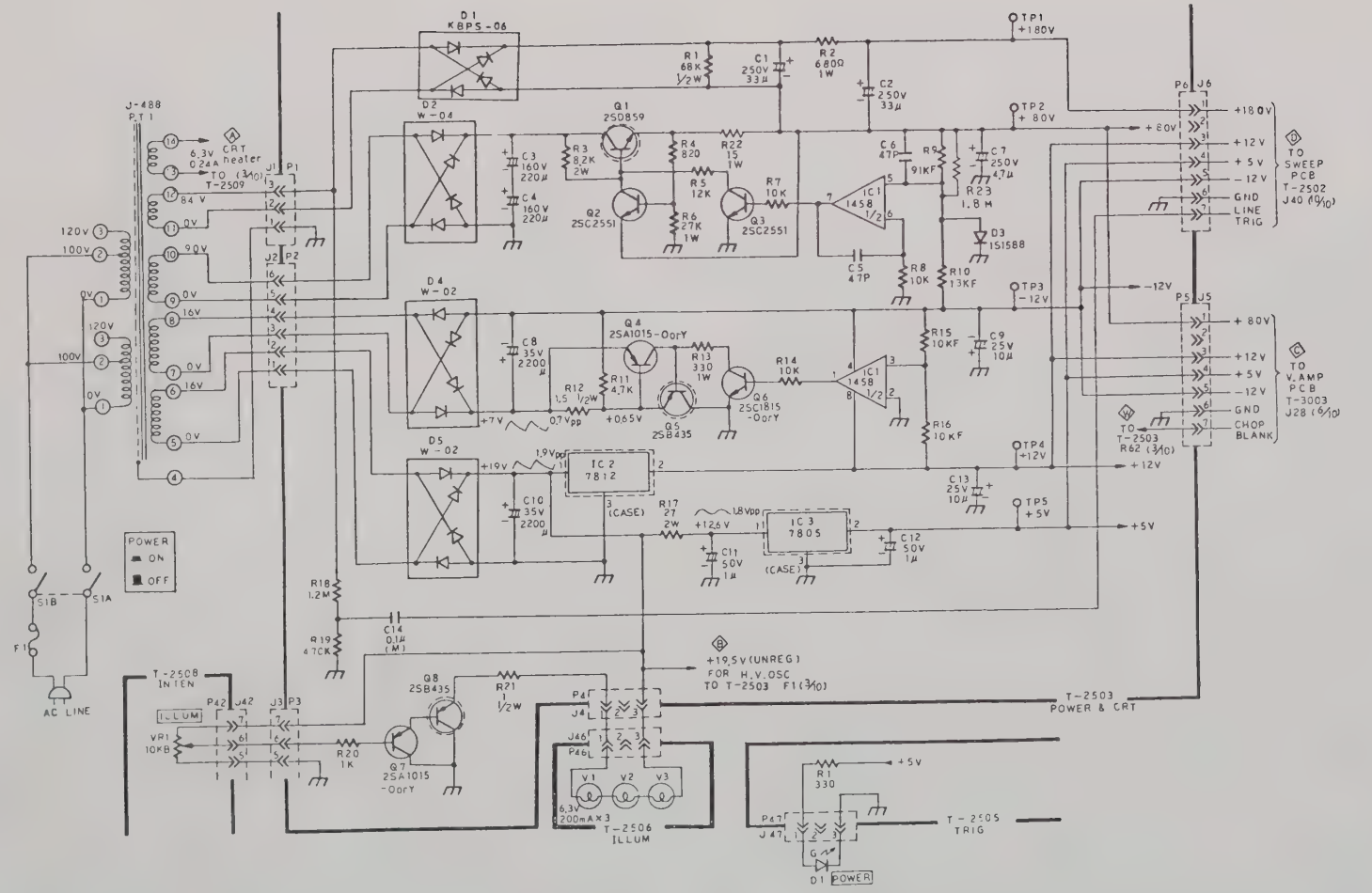


Figure 5-2. LBO-525L Power Supply (Schematic 2 of 10)

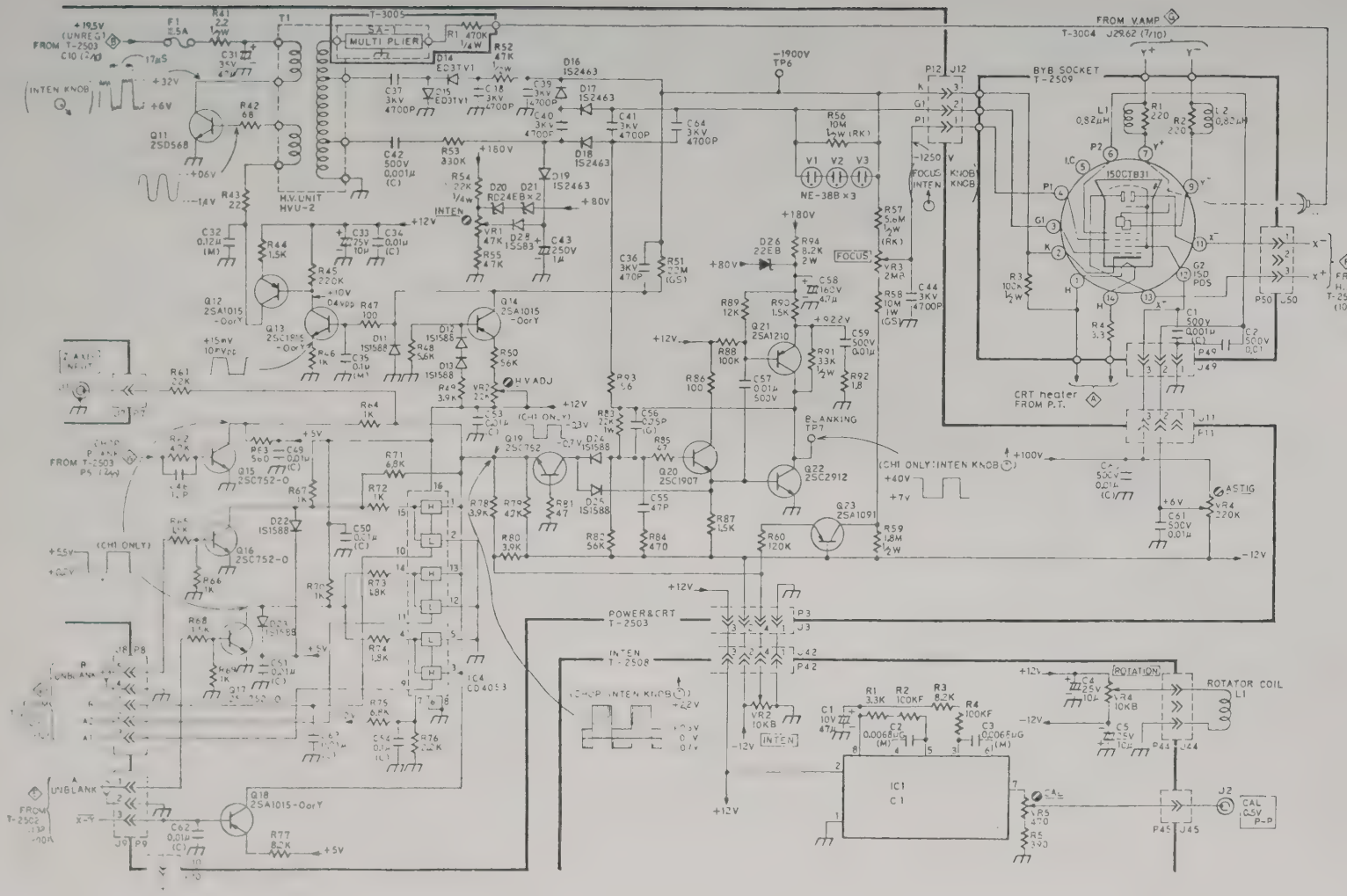


Figure 5-3. LBO-525L High Voltage and CRT (Schematic 3 of 10)

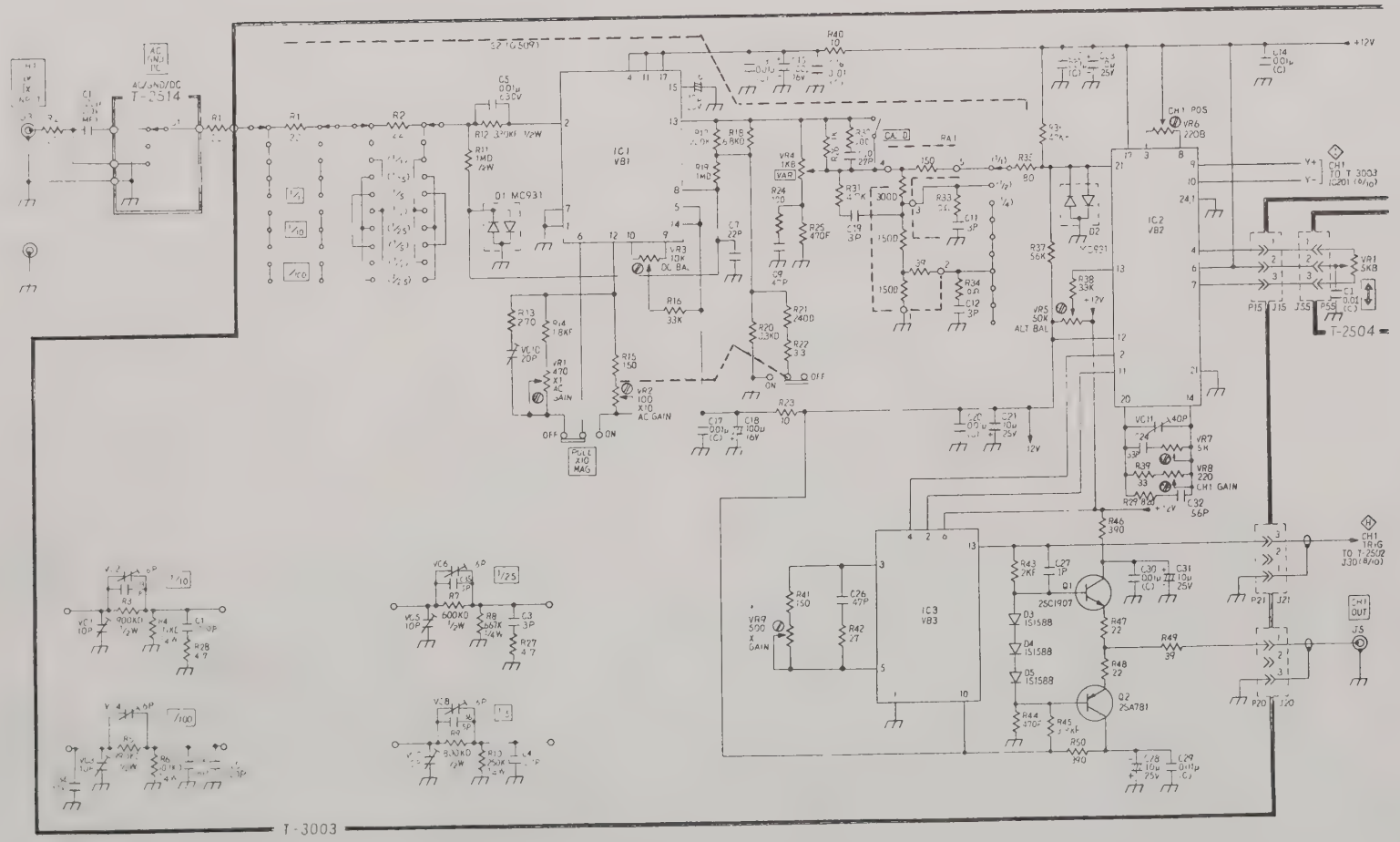


Figure 5-4. LBO-525L Vertical Preamplifier (CH-1) (Schematic 4 of 10)

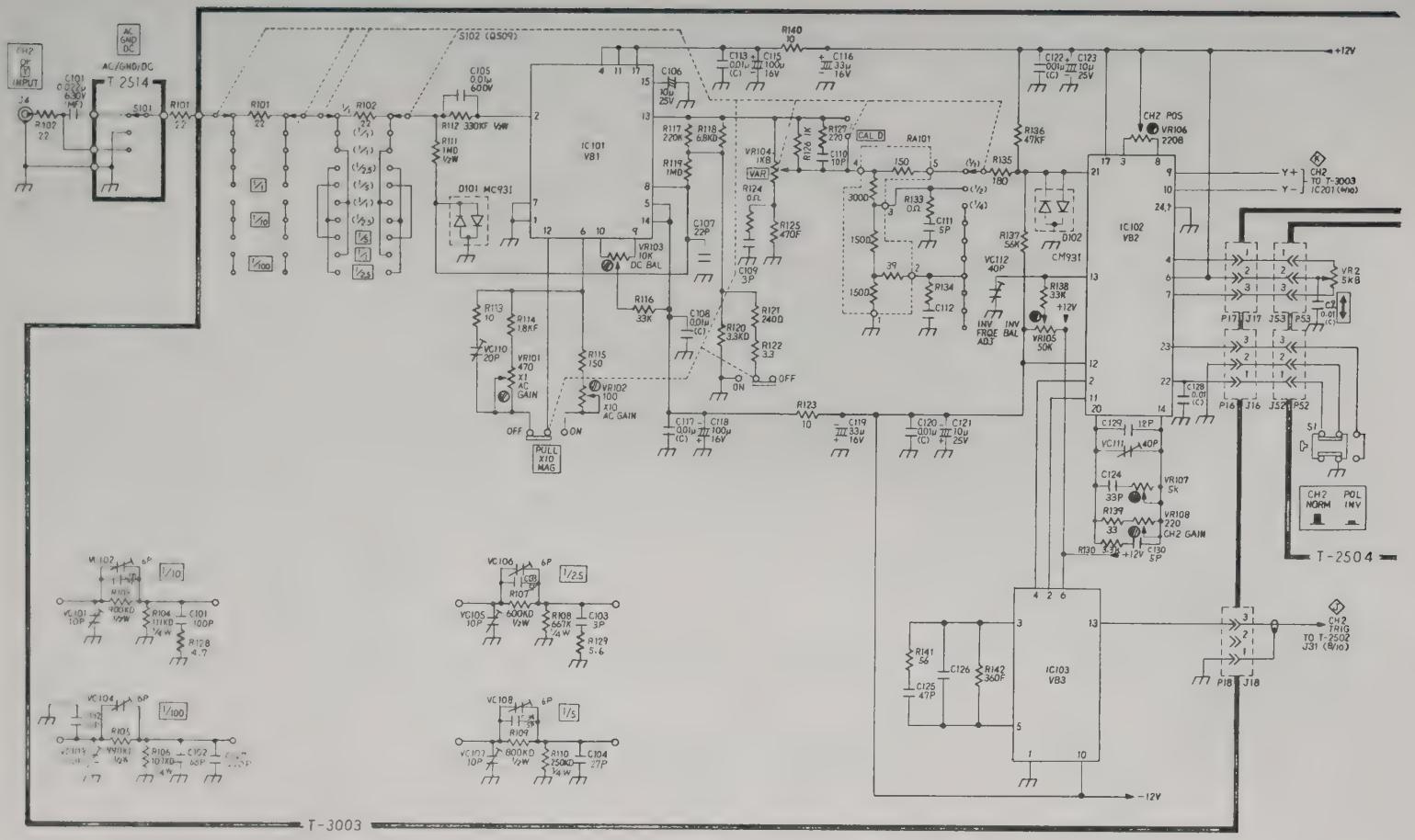


Figure 5-5. LBO-525L Vertical Preamplifier (CH-2) (Schematic 5 of 10)

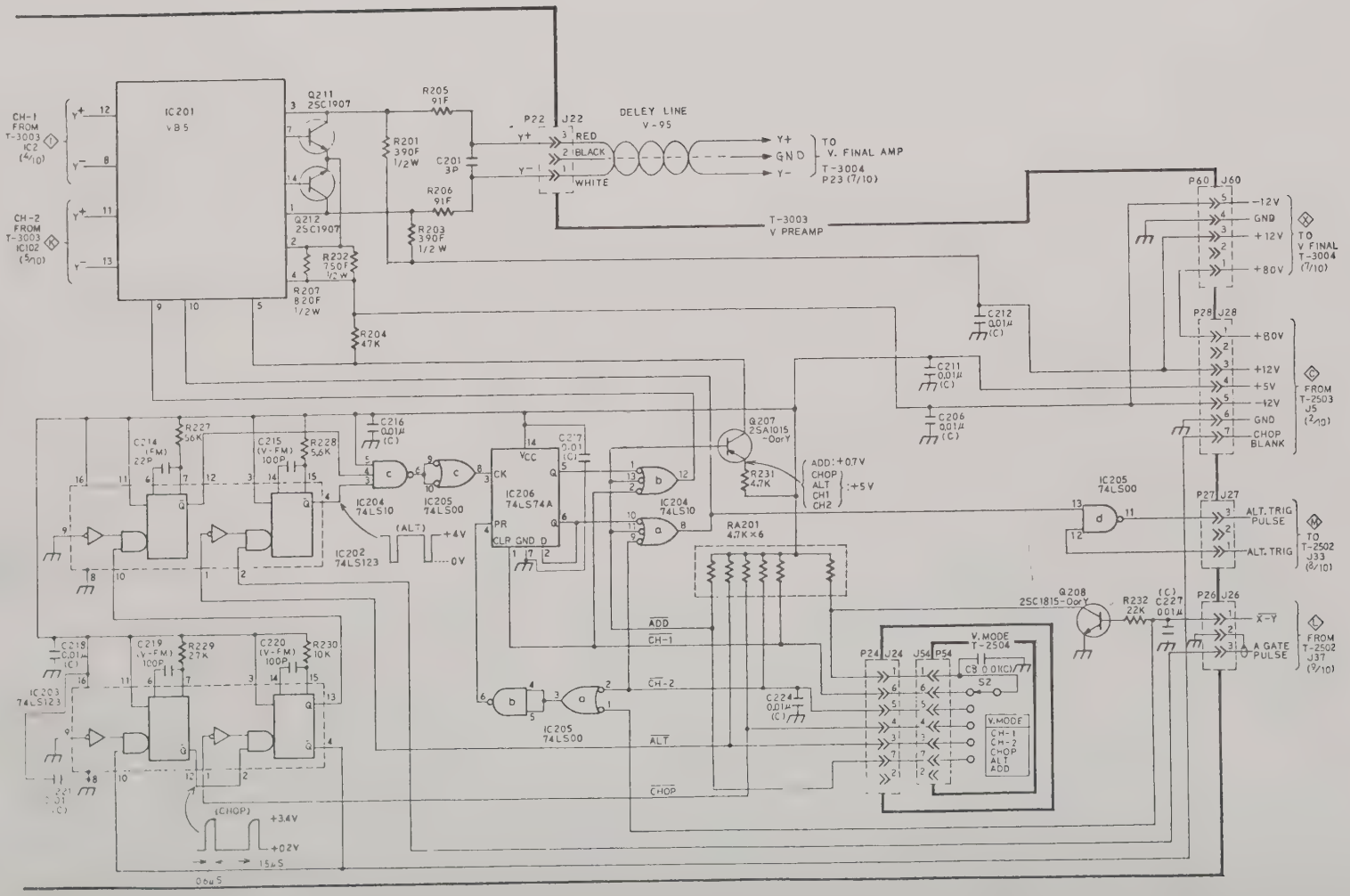


Figure 5-6. LBO-525L Vertical Preamplifier and Mode Switching (Schematic 6 of 10)

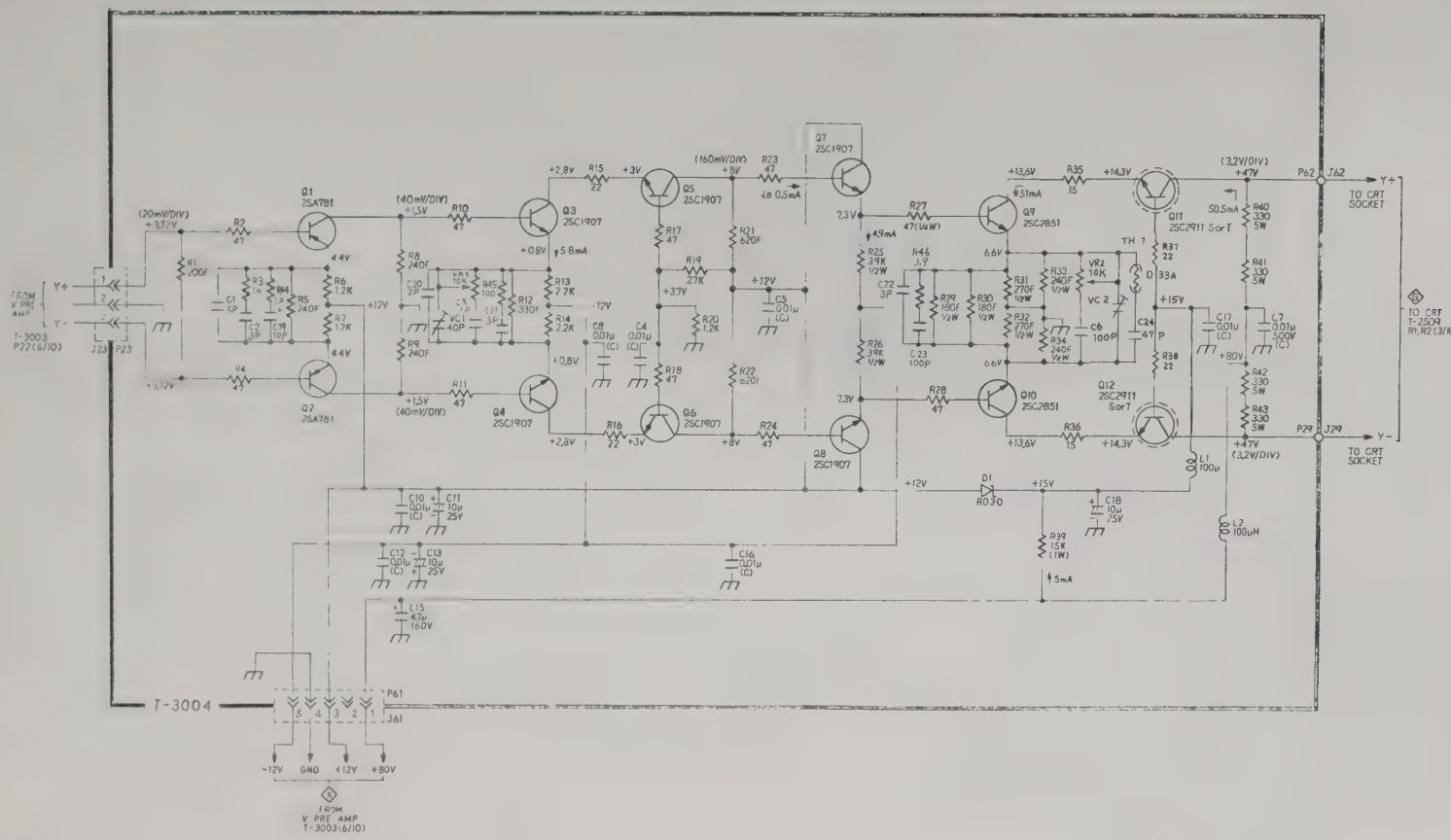


Figure 5-7. LBO-525L Vertical Final Amplifier (Schematic 7 of 10)

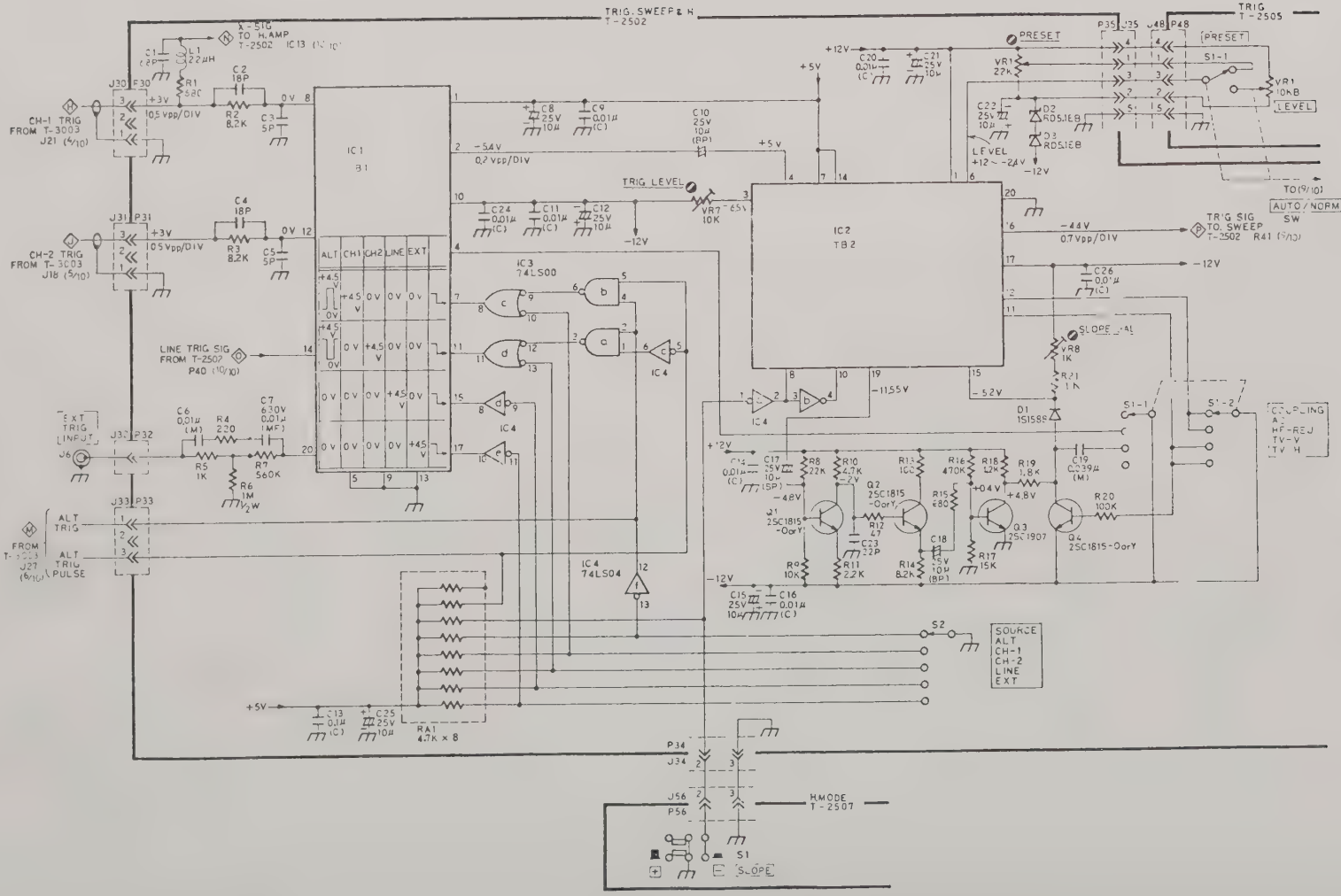


Figure 5-8. LBO-525L Trigger Amplifier (Schematic 8 of 10)

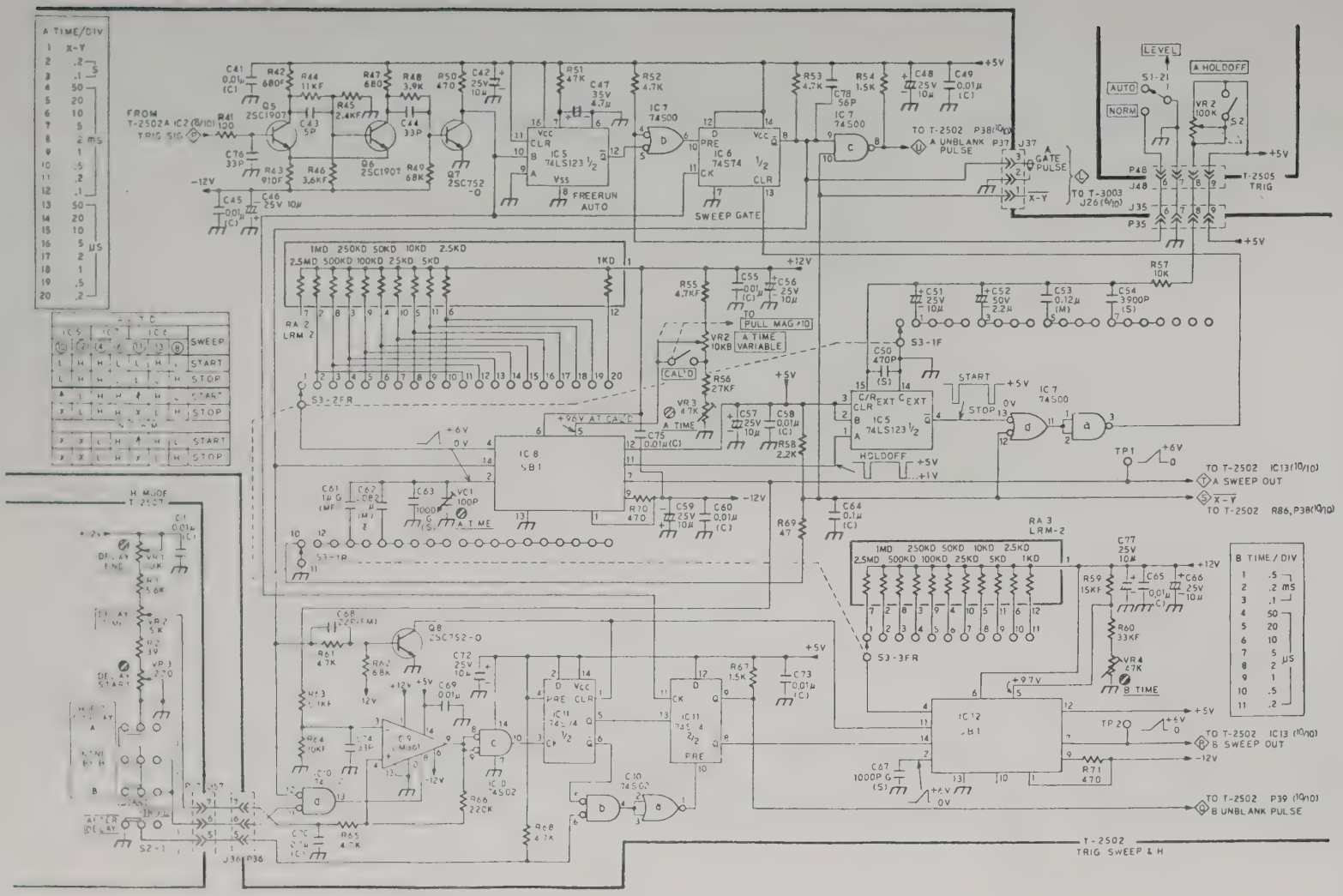


Figure 5-9. LBO-525L A, B Sweep (Schematic 9 of 10)

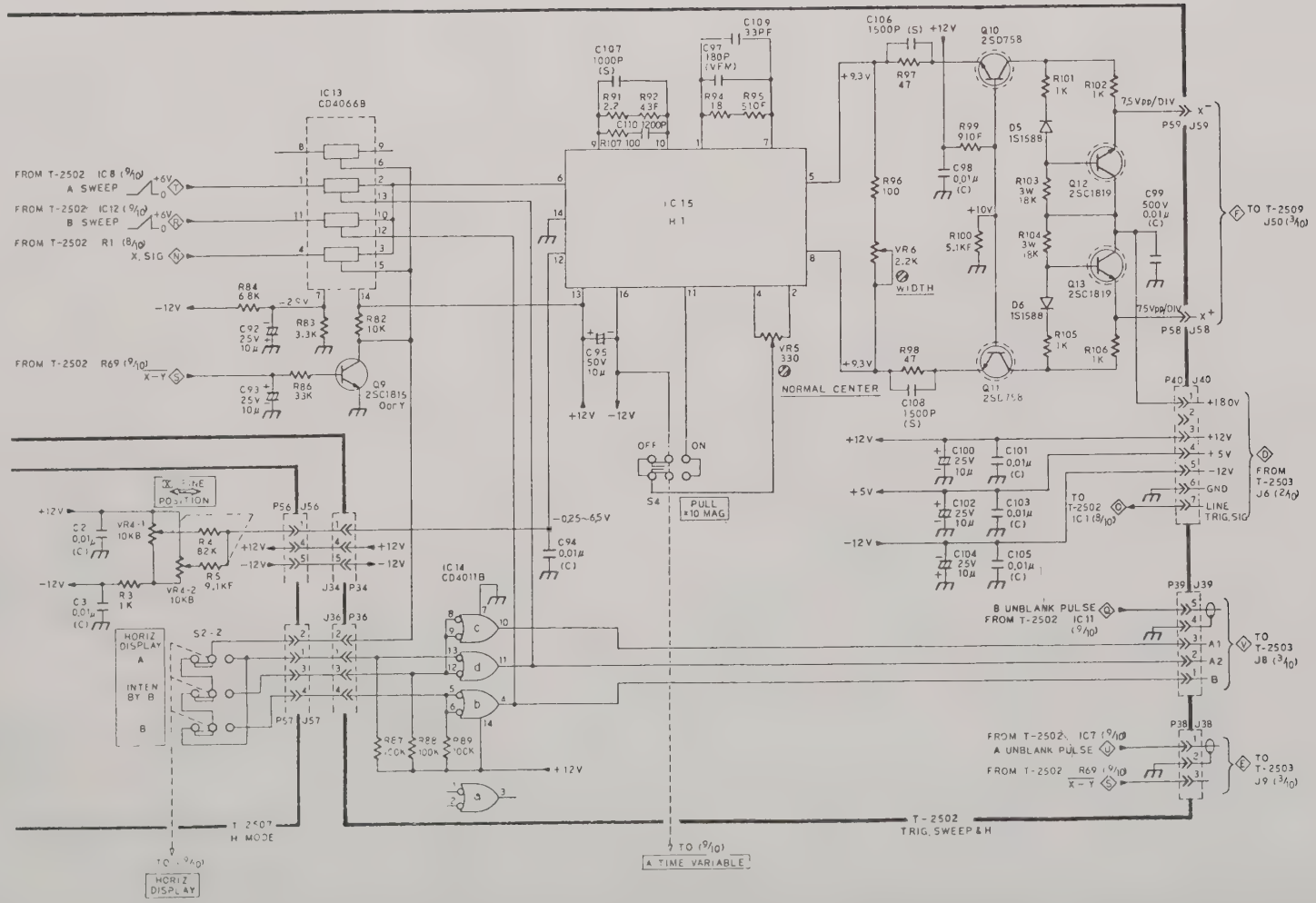


Figure 5-10 LBO-525L Horizontal Amplifier (Schematic 10 of 10)

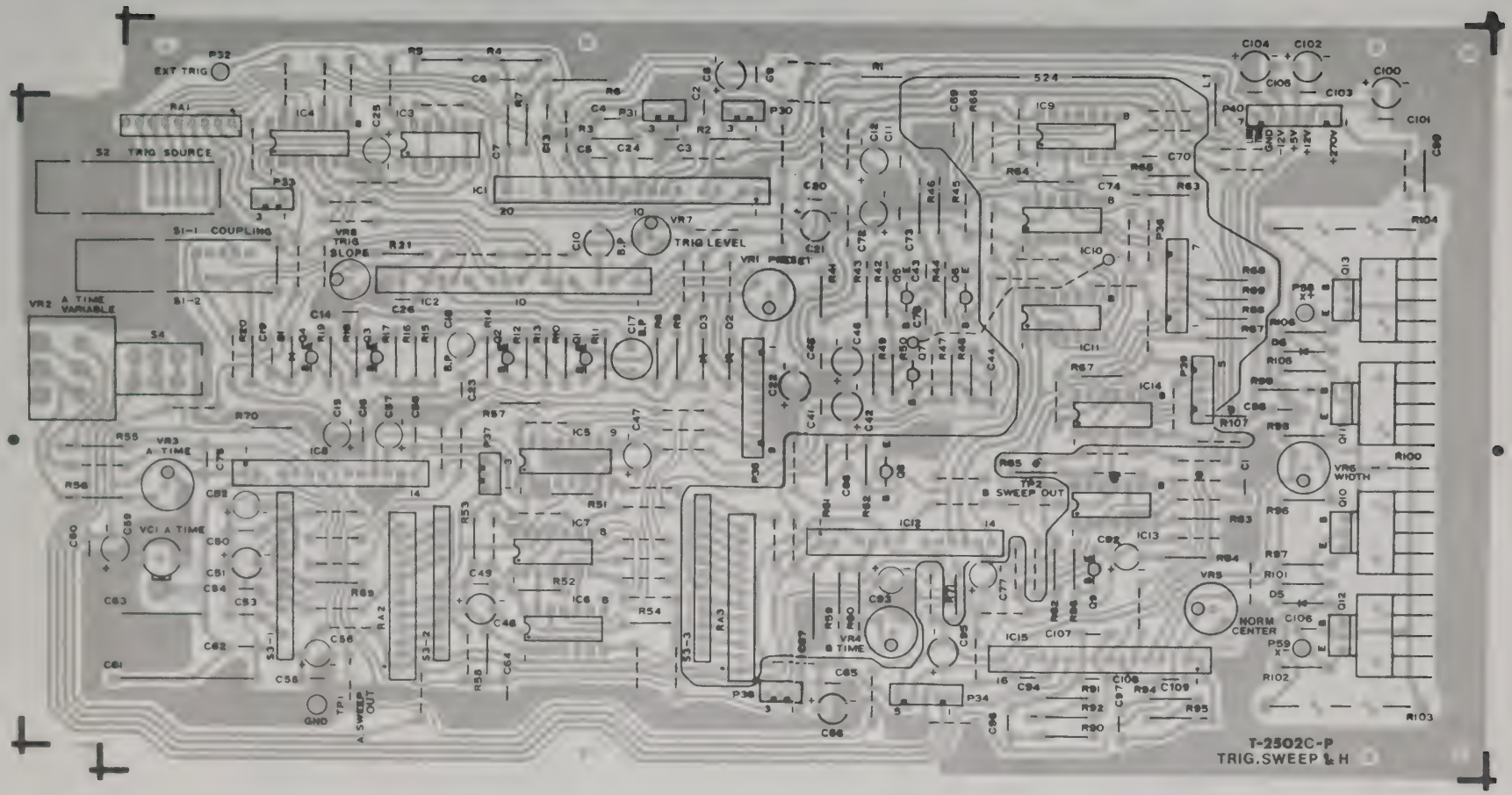


Figure 5-11. LBO-525L Trigger and Sweep P.C. Board T-2502

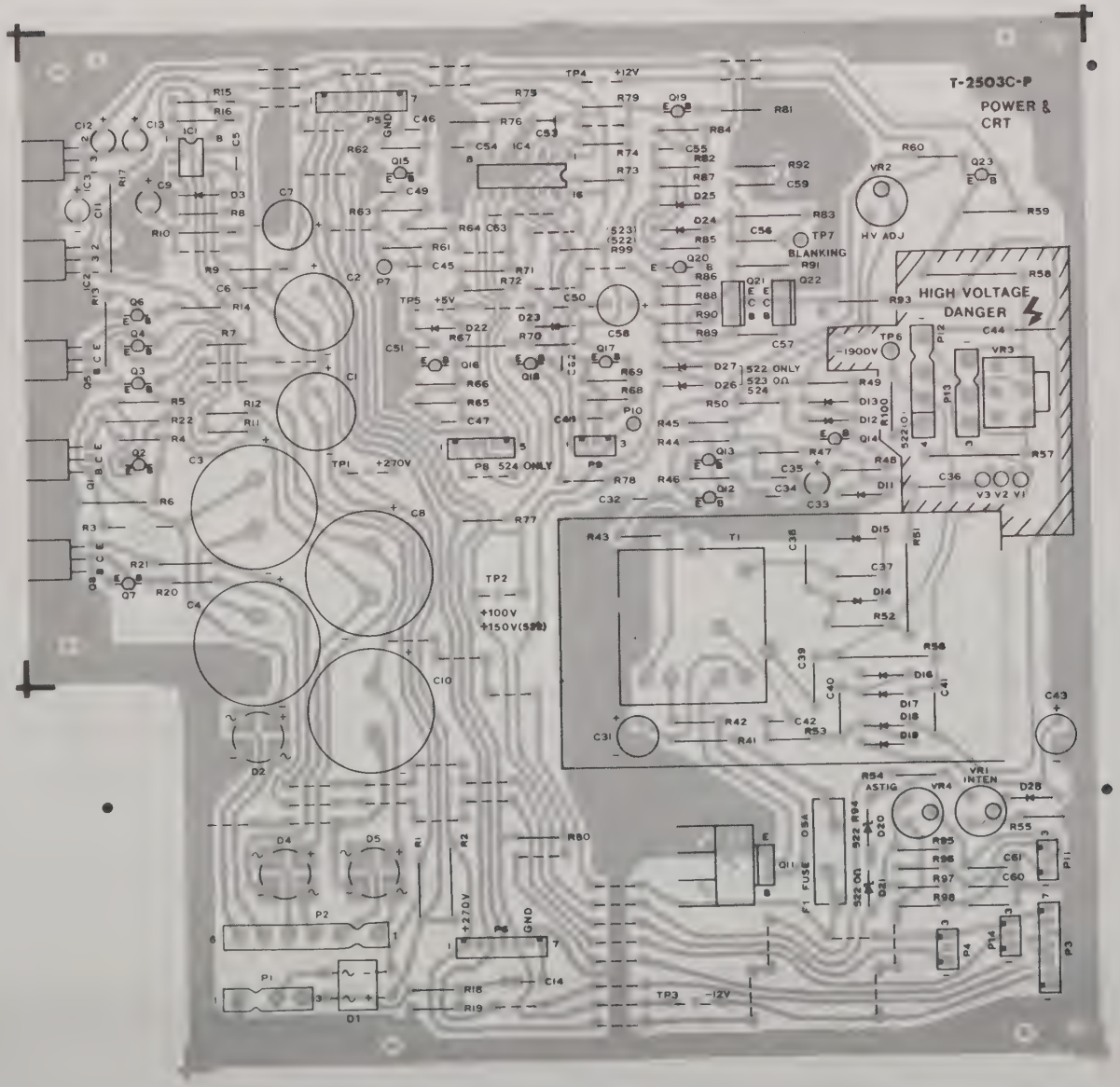


Figure 5-12. LBO-525L Power Supply and CRT P.C. Board T-2503

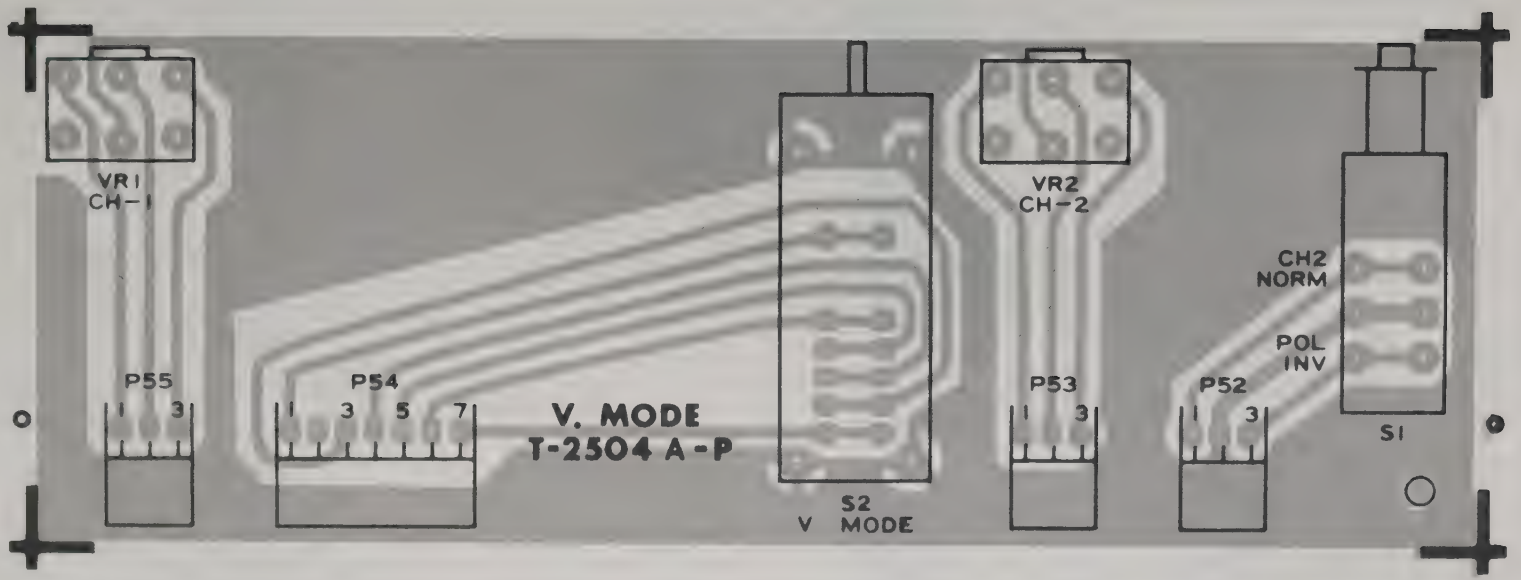


Figure 5-13. LBO-525L Vertical Mode P.C. Board T-2504

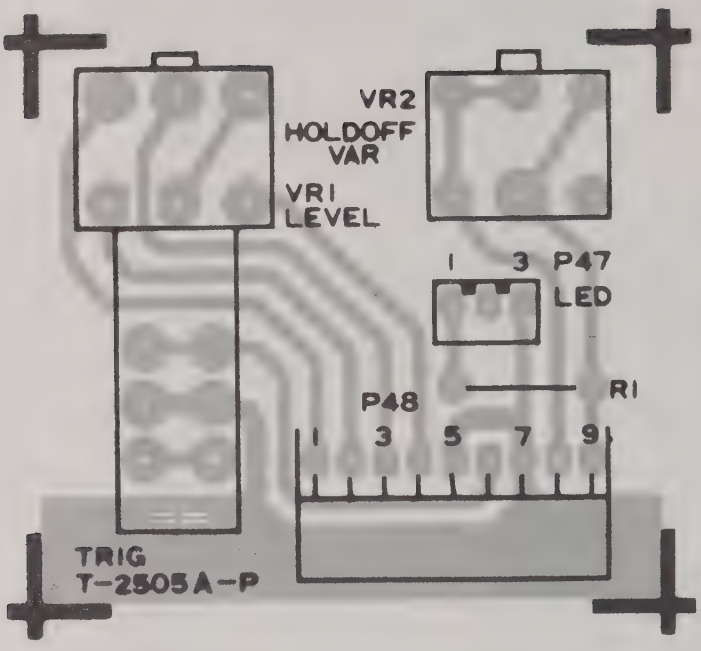


Figure 5-14. LBO-525L Trigger Level P.C. Board T-2505

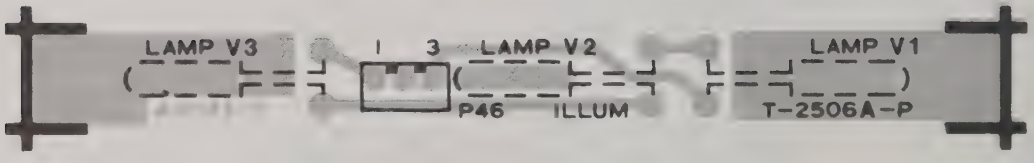


Figure 5-15. LBO-525L Illumination P.C. Board T-2506

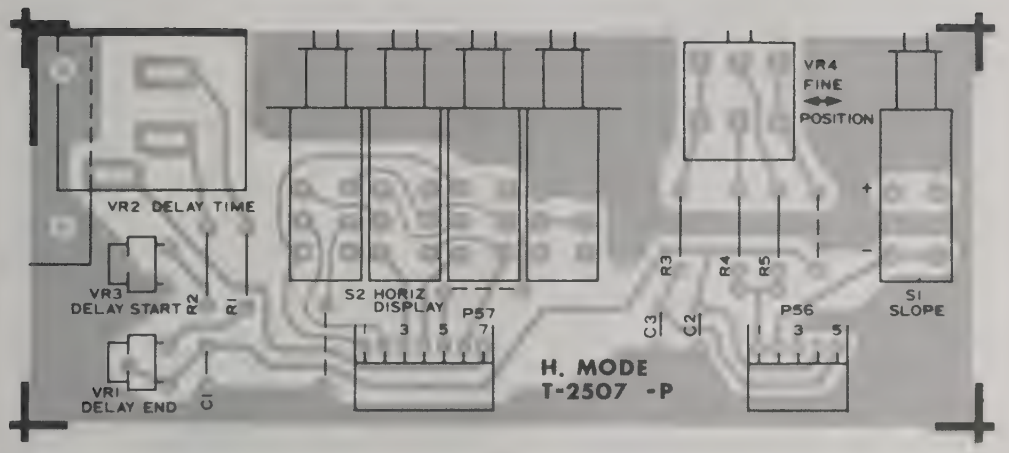


Figure 5-16. LBO-525L Horizontal Mode P.C. Board T-2507

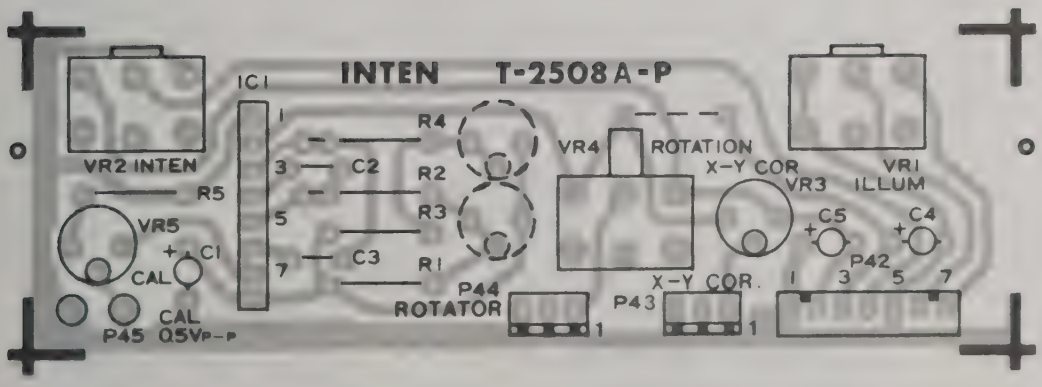


Figure 5-17. LBO-525L Intensity P.C. Board T-2508

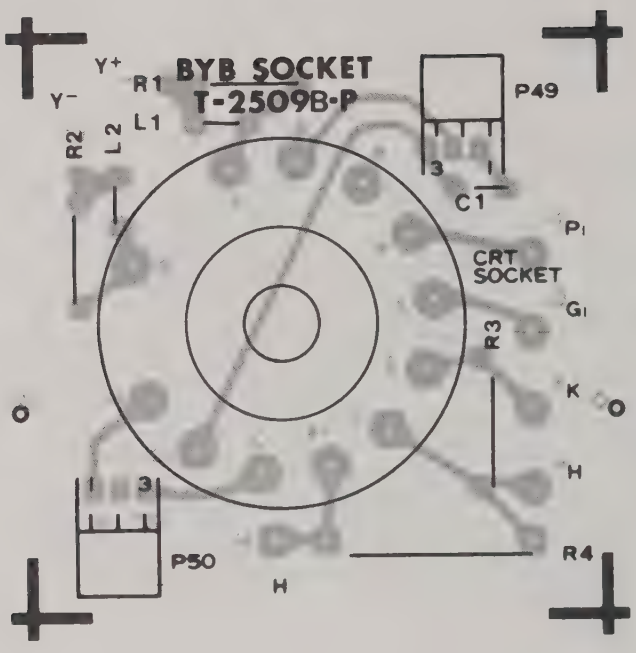


Figure 5-18. LBO-525L CRT P.C. Board T-2509

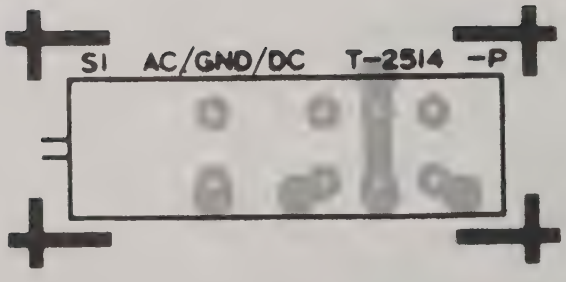


Figure 5-19. LBO-525L AC/GND/DC P.C. Board T-2514

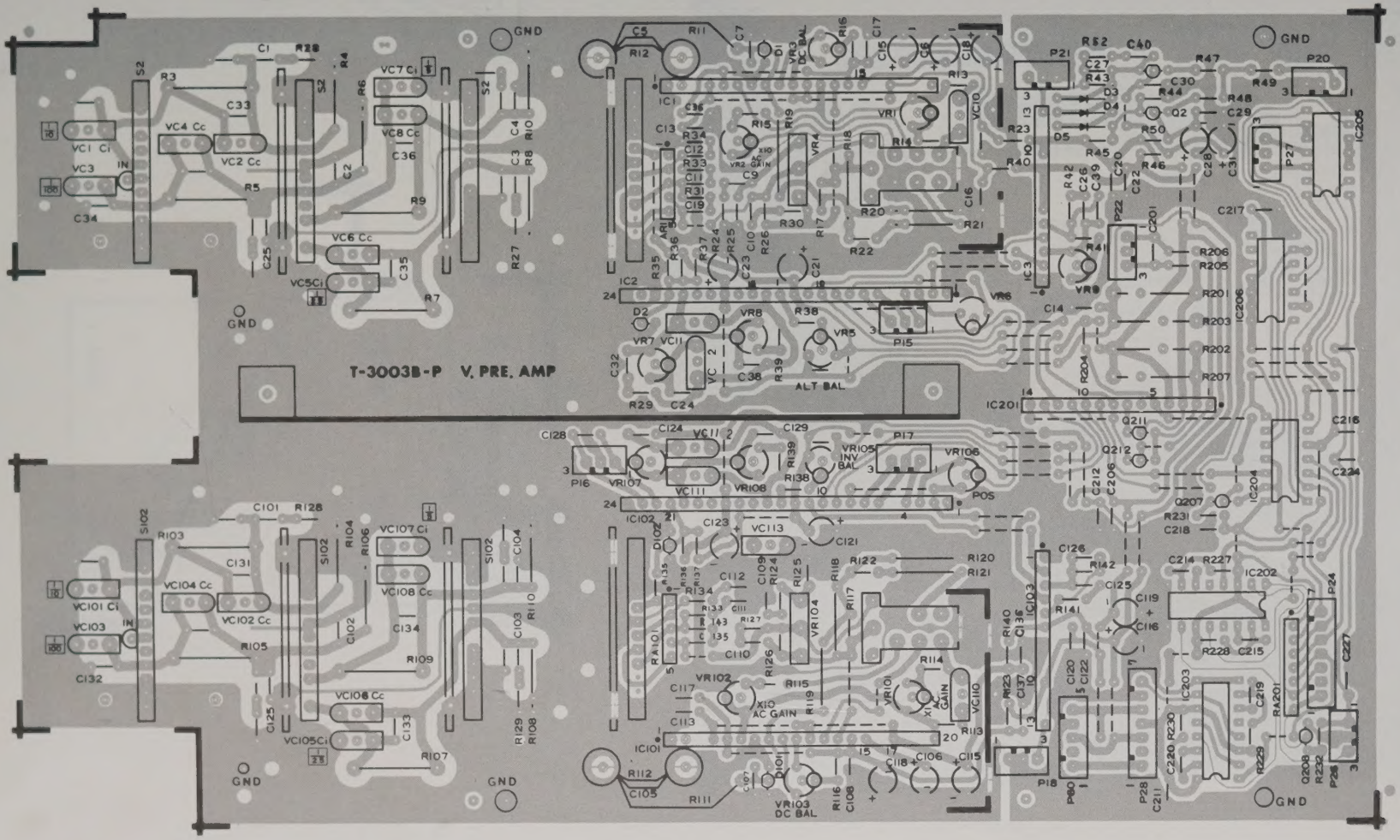


Figure 5-20. Vertical Preamplifier P.C. Board T-3003

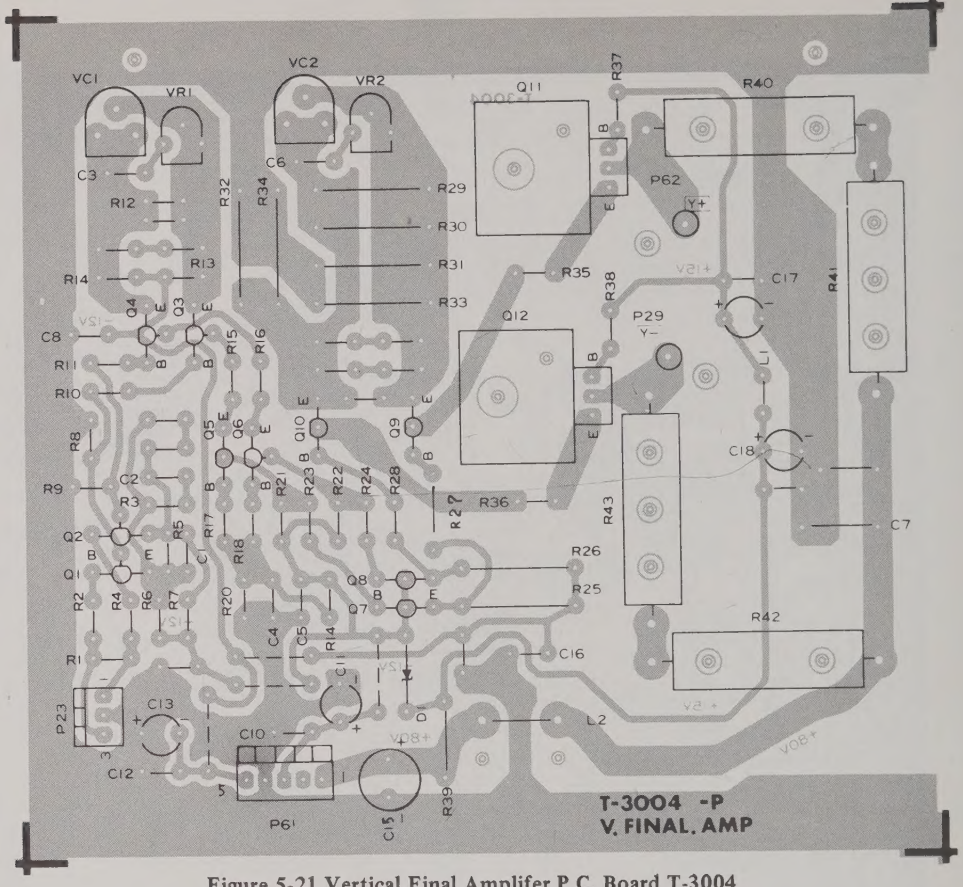


Figure 5-21 Vertical Final Amplifer P.C. Board T-3004

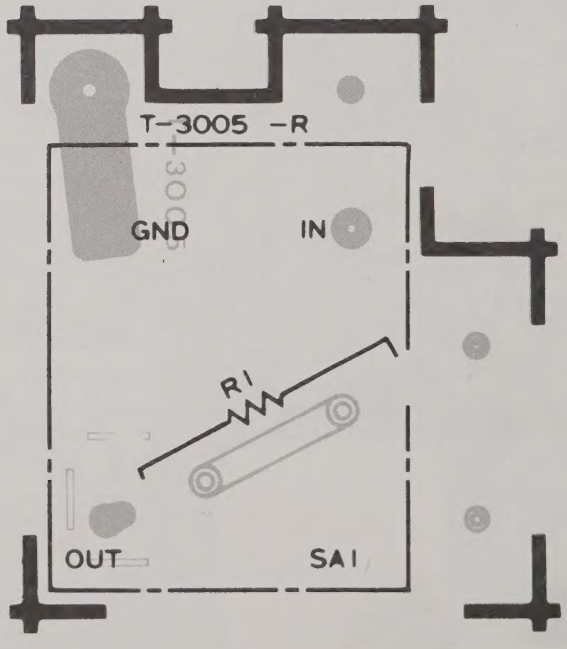


Figure 22. P.C. Multiplier Board T-3005

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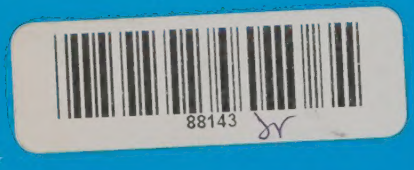

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